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Wright-Patterson Air Force Base, Ohio

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A COST EFFECTIVENESS
APPROACH FOR AIRCREW TRAINING
WITH LASER GUIDED TACTICAL WEAPONS.

THESIS

GSM/SM/73-16

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Major USAF

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A COST EFFECTIVENESS APPROACH FOR AIRCREW TRAINING WITH LASER GUIDED TACTICAL WEAPONS

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

by

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Major USAF

Graduate Systems Management

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Preface

The purpose of this study is to present a methodology which will enable accomplishment of a meaningful evaluation of alternative methods of training tactical aircrews. This topic was a result of my interest in the feasibility of a relatively inexpensive practice laser guided bomb (PLGB) suggested by a fellow AFIT student. During conversations with other persons interested in the development of such a weapon, the factor of "cost effectiveness" was introduced as a valid reason for development of a PLGB. It was the feeling of these persons that a PLGB would be cost effective for aircrew training. The primary reason for this feeling seemed to be that a PLGB would be a replacement for a real laser guided bomb on a one-to-one basis. The real laser guided bomb was assumed to be too expensive to expend for the purpose of aircrew training.

From my experience in the field of tactical aircrew continuation training and from my exposure to the field of cost effectiveness analysis in AFIT, I felt that there should be some effort expended to determine if it were feasible to apply a cost effectiveness approach to evaluation of tactical aircrew training systems. The first major problem area I encountered was the lack of an objective means of measurement of the effectiveness of aircrew training systems and of the combat readiness of the aircrews who use those systems. I feel that this area requires much more study. In order to keep the study unclassified, I have avoided any explicit discussion of tactics, techniques, or classified factors of the weapons systems. The cost data in this study are meant to be illustrative

of the type and magnitude of the cost elements which should be included in an analysis of this type.

I wish to thank all the aircrew members who granted me personal interviews and who shall remain anonymous. I also wish to thank Mr. Joe Cain and Major Bill Letzkus of the AFIT Systems Management Department for the important help given me in the art of conducting a study of this type. I hope that I have done justice in Appendix B in explaining the method of measuring aircrew proficiency that Mr. Cain proposed during a discussion with me in September of this year. I feel that the method proposed by Mr. Cain is important and worthy of further study and evaluation and it should be considered as a topic of study for future theses.

I especially wish to thank my wife, Judy, for her generous support and understanding throughout my existence as an AFIT student.

C.G.K.

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Abstract

This study is directed toward development of a methodology to help identify optimal aircrew continuation training systems for use in the tactical air forces. The area of training for employment of laser guided weapons was selected to provide a realistic example for an illustrative cost effectiveness analysis. Data obtained from interviews with fourteen aircrew members with laser combat experience were used to establish estimated aircrew continuation training requirements for five mutually exclusive alternative methods of training for employment of laser guided weapons.

The main criterion used to evaluate the effectiveness of a proposed aircrew training system was whether or not it was judged by the individuals interviewed to be capable of maintaining an acceptable level of combat readiness for the tactical air forces. Ten sub-criteria for tactical aircrew training systems were developed and applied to the five alternative ~~training~~ systems. Examples of the estimated economic costs of the resources required for each alternative to produce the required level of combat readiness were provided for purposes of cost comparison of the alternatives. Further study is suggested for a satisfactory method of measuring the effectiveness of laser tasked aircrews.

Chapter I

INTRODUCTION

Statement of the Problem

The tactical air force commander must, as all other military commanders, strive to achieve the highest effectiveness possible with the resources available to him. In peacetime, most of his resources are expended maintaining aircrew proficiency by the accomplishment of simulated combat flights and the employment of training munitions against simulated hostile targets. The training required to maintain aircrew currency and a combat ready status is called "Phase III" or "continuation" training (Ref 4:1-2). To expend these resources wisely, the tactical air force commander must establish training objectives which, if achieved, will enable his force to maintain the effectiveness desired.

The commander must reappraise his particular mix of aircrew training objectives with every change in the total amount of known present and predicted future resources available to him. Due to the multiplicity of possible tactical requirements in actual combat and the lack of definite cost and effectiveness trade-off relationships between the training alternatives, this reappraisal is presently accomplished by seasoned intuition on the part of the commander or his staff.

Objective of the Study

The writer will conduct an illustrative analysis of one area of tactical aircrew continuation training to determine if a systematic approach, or methodology, can be established which will help to identify the optimal training system in that tactical aircrew training area. The area selected is that of aircrew training for laser guided weapons employment. These weapons are a recent addition to the tactical weapons inventory and firm continuation training procedures and requirements have not been established as of this date.

The following are the reasons why the writer elected to accomplish an illustrative analysis rather than an actual analysis. First, the tactics and techniques required for effective employment of laser guided weapons are, for the most part, classified. This classification limits the discussion allowed in an unclassified study of the relevant requirements imposed upon the alternative training systems by these tactics and techniques. Second, the cost data which would be required for an actual analysis are dependent upon the exact tasking of the tactical air forces with regard to the laser guided weapons. The decision on the exact mix of future forces will be a high level decision and the exact mix is likely to be classified. Third, to use a mix of cost data, some of which are exact (from estimates that are documented in official cost estimating documents) and some of which are purely speculative, could convey a measure of reliability to the speculative data which could be unwarranted. Cost estimating is a science in itself and to realistically estimate the cost data required for this study would require considerably more time than was available for the entire study.

The term system as used in this study is defined as: "The composite of equipment, skills, techniques (including all related facilities, equipment, materials, services, and personnel) that is capable of performing and/or supporting an operational role" (Ref 3:1-2). This definition from the Air Force Manual, Instructional System Development, is especially suited for operational training systems. The operational role in the context of this study is the role of aircrew continuation training.

Background of Guided Ballistic Weapons

The Army Air Forces, during the latter years of World War II, developed and deployed several versions of guided ballistic bombs. Ballistic bombs are essentially free-fall gravity bombs. Four of the most important of these are described below.

1. AZON - an assembly was attached to an ordinary 1000 or 2000 pound free-falling bomb which permitted control of its trajectory in azimuth only. This bomb was used for line of communication targets such as, bridges, roads, and railways. After release from the carrier aircraft, a million-candlepower flare enabled the bombardier to visually make azimuth corrections. This weapon required the aircraft to make a steady run after dropping the bomb until the bomb impacted, thus increasing the probability of flak damage (Ref 1:88).

2. RAZON - similar to the AZON, except that it could be controlled in both range and azimuth. A little more accurate than the AZON, it required the same hazardous bombing run (Ref 1:88).

3. GLOMB - a remotely controlled glide bomb with a wing twelve feet long attached to the bomb. A television transmitter was installed in the nose to relay the flight picture back to the bombardier. This enabled the B-17 carrier aircraft to release it at an altitude of 15,000 feet up to 17 miles from the target and execute a 180 degree turn to exit the area while the bomb was guided to impact by the bombardier (Ref 1:88).

4. ROC - a glide bomb developed near the end of the war on which the aerodynamic control surfaces were incorporated in a circular wing structure which surrounded the belly of the bomb. Although similar to the RAZON, these aerodynamic controls provided three times the maneuverability of the RAZON (Ref 1:89).

Despite this strong start with guided bombs nearly thirty years ago, operational guided ballistic bombs are only a recent addition to the tactical arsenal of the United States Air Force. Conventional non-nuclear weapons, in general, were not improved during the years from just after the Korean War until the early nineteen-sixties. The emphasis, during that time, was on strategic airpower and the tactical air forces were mainly oriented to supplement the strategic nuclear strike forces.

Operation of Laser Guided Weapons

Operations in Southeast Asia during the middle sixties identified definite needs for some sort of tactical guided weapons on some types of targets, and the laser guided bombs were conceived to fill these needs (Ref 40:1). Within the last six years, the family of laser guided weapons has been developed and introduced in combat in Southeast

Asia where they have been credited with extremely good results against both lightly and highly defended point targets. The first combat release of a laser guided bomb was on 24 May 1968 (Ref 40:4).

The accuracy of these laser guided bombs is much improved over that of unguided "iron" bombs. For example, a writer for Aviation Week & Space Technology stated that over half of the laser guided bombs were direct hits during a sample period when these bombs were initially used in combat. At that time, the pilots of the F-105 fighter bombers were said to be able to deliver the ballistic iron bombs with an average accuracy of roughly 250 feet (Ref 27:48-9).

This greater accuracy of the laser guided bombs is provided by an expensive laser seeker and guidance unit which is mated to the nose of an ordinary 500, 750, 2000, or 3000 pound high explosive, iron bomb. This laser guidance unit increases the cost of the complete weapon to four or five times that of the unguided bomb (Ref 27:48). The laser unit is designed to guide the bomb to impact on an intense, narrow beam of laser energy which is trained on the designated target by the attacking force.

The operational laser guided weapons, which are referred to as Paveway munitions, are delivered in a manner similar to unguided ballistic weapons. The aircraft which carry and expend laser guided weapons require no special modifications nor electrical interconnects. Any aircraft that is capable of carrying ordinary unguided weapons can be utilized to carry laser guided weapons (Ref 40:6).

The aircraft which provides the laser energy does require modification. However, the modification does not degrade the normal weapons delivery capability of the laser aircraft.

The major components of a laser guided bomb are shown in Figure 1. Fixed wings are attached to the aft end of the bomb body to provide aerodynamic stabilization. The laser seeker and control section is mated to the forward end of the bomb. Upon weapons release, a thermal battery is fired which activates the guidance circuits after a 3.5 second safe-separation delay. If there is no laser energy reflected from the ground within the limited field of view of the laser seeker, the weapon will fall ballistically. When laser energy is detected by the seeker head, the control fins are immediately deflected to correct the flight path of the weapon (Ref 40:6). The corrections are continued until weapon impact.

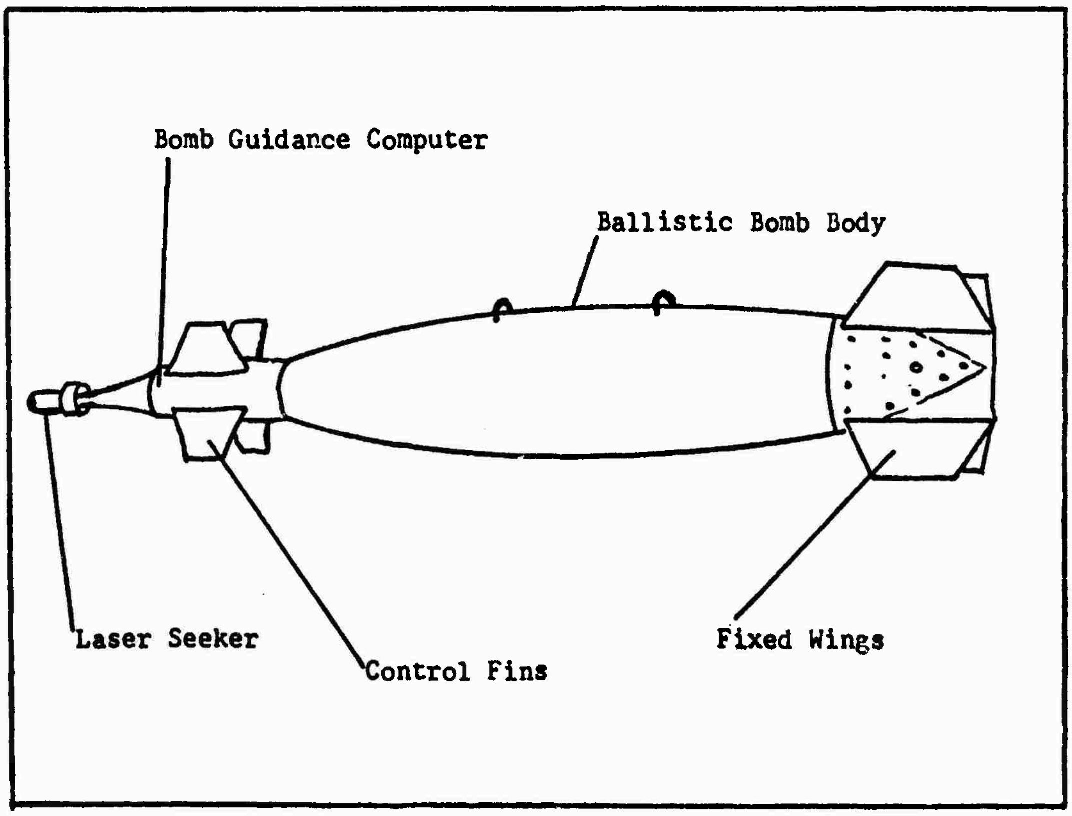

Figure 1. Major Components of Laser Guided Bombs.

Paveway bombs may be compared to the earlier AZON, RAZON, and ROC weapons in that the laser aircraft must remain in sight of the target until weapon impact. Since the laser guided bomb has no self-contained propulsion capability, it must be released within certain parameters of aircraft dynamic loading, airspeed, altitude, relative target bearing, and slant range to the target in order to hit the target. This group of parameters is referred to as the "release basket."

Aircrew Training for Employment

Presently, the training of tactical aircrews for employment of laser guided munitions is accomplished by their dropping a twenty-five pound unguided training bomb, the BDU-33, within the basket of parameters mentioned above and noting the distance that the bomb impacts from the desired target on the bombing range. The skill of the aircrew member in the back seat of the aircraft who "designates" or "illuminates" the target with the laser beam is measured by his aiming a laser illuminator on the target until bomb impact. The illuminator contains a device which provides a filmed record of the position of the actual aim point of the laser beam during the time of flight of the training bomb. If it is determined that the practice bomb was released within the basket and the illuminator was on the target at the correct time, the aircrew is credited with an effective bomb. The most difficult skill to develop is that of the constant illumination of the target during the time of flight of the bomb. This is mainly due to the pilot continuously changing the aircraft flight path to avoid being easily tracked by antiaircraft weapons in the vicinity of the target.

There are several other methods which may be projected for possi-

ble use for tactical laser guided munitions training. Training with the actual weapon is quite expensive and not generally considered feasible. One less expensive alternative might be the development of and use of a reliable low cost practice laser guided bomb which would provide realistic flight characteristics very much like those of the real weapon.

Another possible method of training is through use of a fully instrumented electronic air-to-ground bombing range which would require no expenditure of ordnance. The electronic system would be capable of precisely measuring all the parameters of the aircraft at the instant that the aircrew simulates release of a laser guided weapon. A computer could then compute the predicted target miss distance from these data. Admittedly an expensive proposition, a range with this capability would have numerous other spillover uses in the tactical operations training field. Other alternatives will be presented and discussed in this study.

Research Methodology

The method of evaluating and comparing alternative training systems that will be used in this study is that of economic analysis. The view of Dr. Alain C. Enthoven may be even more appropriate today than it was ten years ago when he stated that choosing weapons systems:

> . . . is fundamentally an economic problem, using the term in its precise sense. That is, it is a problem in choosing how best to use our limited dollars and limited resources valued in dollars, such as man hours, materials, plant and equipment, etc. To do this properly, one must think through the purposes of the weapons systems, formulate good criteria of effectiveness, and then consider alternative systems or mixes of systems in terms of their effectiveness and their cost (Ref 14:155).

This economic analysis method is referred to as systems analysis. It is a method by which the relevant data may be organized in a very useful fashion when it is presented to the responsible decision maker.

The approach used in this study is called cost effectiveness analysis. It may be considered as a subset of systems analysis. This cost effectiveness approach is designed to aid the command level tactical air forces decision maker when making his decision by comparing various alternative aircrew training systems in terms of their costs and in terms of their effectiveness in achieving his aircrew training goal.

Research for this study was accomplished in three major areas. They are the area of cost effectiveness analysis, the area of aircrew training effectiveness measures, and the area of critical factors of the effective employment of laser guided weapons. Additionally, research was conducted in the area of cost estimating techniques.

Research in the four areas was accomplished through extensive review and study of the current and recent literature and through personal interviews with experts who have special skills or knowledge in the various areas of importance to the study. Research of the area of cost effectiveness analysis was accomplished in order to determine the suitability of the cost effectiveness approach for the problem. Research in the area of aircrew training effectiveness measures was required to determine if there were any measures presently in use which would be acceptable for use in this analysis. Research of the essential factors of effective employment of laser guided weapons was conducted through a number of interviews of experts in the fields related to the employment of tactical laser guided weapons. Research in the classified documents included in the bibliography was limited to the

unclassified portions of those documents.

The research of the literature and telephonic interviews were conducted during the months of June, July, August, and September of 1973. The personal interviews were conducted at Langley AFB, Virginia, in June 1973 and Eglin AFB, Florida, in August 1973.

The writer is solely responsible for the development of the subcriteria presented in Chapter III as well as the tactical weapons systems critical factors presented in Chapter IV. Additionally, the statements in the illustrative evaluation of the alternative training systems in Chapter V are based upon subjective judgments by the writer. The writer has served in all three tactical air commands and was a "combat ready" pilot in the F-4 aircraft from 1964 until 1972 and, additionally, has been actively involved in F-4 aircrew continuation training from September 1963 until May 1972.

Data which provided the basis for computation of the individual aircrew requirements of each independent training system were obtained from interviews with fourteen aircrew members who had combat experience with laser guided weapons. Specific sources of data which appear in the study are cited in the bibliography.

The cost data in this study are meant to be representative of the relevant estimated costs for an analysis of this type. The basic purpose of this study is to develop a systematic approach which will help identify the optimal tactical aircrew training system for employment of tactical weapons. As long as the techniques utilized are judged for their validity, it should not be important that the examples of estimated costs in this study are not precisely accurate.

Elements of an Economic Analysis

The economic analysis of the aircrew training problem which will be pursued in the following chapters contains the following elements of economic choice which are identified by Hitch and McKean (Ref 18: 118-120):

1. An objective or objectives. What is the objective of tactical aircrew training? If the wrong objective is selected the whole analysis is directed to the wrong question. Determination of the best objective of aircrew continuation training is addressed in Chapter II.

2. A model or models. A model helps to trace the relations between inputs and outputs, or resources and objectives for each of the training systems which will be compared. The combat readiness approach presented in the latter portion of Chapter II is the subjective model used to determine the amount of each training system required to achieve the objective.

3. A criterion. Hitch and McKean describe a criterion as simply a test by which a choice is made among alternative systems. They note that frequently the central problem in designing a systems analysis is the choice of an appropriate economic criterion (Ref 18:120). This is so in the determination of a criterion or several criteria for judging the effectiveness of a tactical aircrew training system. The criteria used in this study are presented in Chapter III and applied to the alternative training systems in Chapter V.

4. Alternatives. It is necessary to identify and develop

all feasible alternatives to achieve the stated objective or objectives. The alternatives will be referred to as alternative training systems in this study and this element will be studied in Chapter IV.

5. Costs or resources used. Each feasible alternative will "cost" something; if not dollars then some other resource such as available personnel or a sacrifice of some other mission. Determination of estimated costs and other related factors will be accomplished in Chapter VI.

Scope and Assumptions of the Study

The period of time that the study is assumed to encompass will be from 1974 through 1980. This span of seven years is selected in order to present a realistic analysis of alternative comparison over time. It is possible that an alternative which is viable for this time period would still be attractive for use beyond 1980, but the value of this future benefit will be assumed to be insignificant for the purpose of this study.

The scope of aircrew training in this study will be limited to aircrew continuation training in the three major air commands which have the responsibility for maintaining combat ready tactical forces--PACAF, TAC, and USAFE.

The following are the basic assumptions of this study:

1. The laser guided weapons and laser designator systems to be utilized during the time period of this study will be similar to those in use today for their demands on aircrew performance.

The weapons and laser designator systems reviewed in this study will likely be the primary means of employing laser guided ballistic weapons through 1980. This is due to the planned procurement of large numbers of both the newest designator system and the laser guidance kits. The writer maintains that any new weapons or designator systems developed and deployed before 1980 will require aircrew actions similar to those aircrew actions required by present laser weapons systems.

2. The F-4 aircraft will continue to be the main tactical fighter used for illumination and employment of laser guided weapons during the time period of this study. This assumption is based upon the fact that present laser guided weapons systems require a two man aircrew to illuminate the target and to release the weapons. There are no other two man fighter aircraft in operation or development at the present time which will possess this capability.

3. Initial laser guided weapons training will be effective in the production of combat ready aircrews. This assumption implies that the average aircrew will have achieved the desired level of proficiency or competence when they complete the initial checkout program. If this goal is achieved, then the primary task of aircrew continuation training will be the maintenance of the combat ready status of the aircrews.

4. There will be some degree of specialization of missions (e.g., air-to-ground, counter-air, nuclear strike) at the wing level in the tactical air forces. This will be due to the fact

that present weapons technology can provide more aircraft capability than one aircrew can master. To compensate for this it is assumed that only certain wings of tactical fighter aircraft will be modified for the laser designator systems. All squadrons in these wings will then possess the capability to designate for and to employ laser guided weapons and, consequently, will be required to conduct continuation training for this task. The tactical fighter wings that possess the unmodified aircraft will have the capability of releasing laser guided weapons if laser energy is provided by some other source. These wings of unmodified aircraft will likely be required to specialize in some other tactical role and are assumed not to conduct laser guided weapons continuation training.

5. It is assumed that the total number of flying hours authorized for the tactical air forces will not be adjusted due to demands imposed by the different aircrew training systems. This means that if a particular alternative system requires more flying time than the other alternative systems, then that flying time must be taken from some other area of training if that alternative is selected. In the past, flying hour allotments have not necessarily been correlated with demands for aircrew training.

Limitations of the Study

Four major limitations of this study are comparable to those which have been identified with other similar studies (Ref 32:361-3). First, analyses are necessarily incomplete. The continuous pass-

age of time, if nothing else, will insure this incompleteness. Even with no limitations of time or money all of the relevant considerations can not be treated--some are too intangible to be treated.

Second, measures of effectiveness are inevitably approximate. The objectives of national defense drive the quality of the effectiveness measure of the military departments. These national defense objectives are often multiple objectives, ill-defined and sometimes conflicting. This creates an understandable inability to determine good measures of effectiveness, which, in turn, creates a severe limitation on the usefulness of any analysis.

Third, no satisfactory way exists to predict the future. This important factor should be brought to the reader's attention in any defense analysis. Because of this uncertainty as to the future, any analysis should consider the entire range of possibilities. For example, we should not automatically assume that our next military task will be in the jungles of Southeast Asia or in Central Europe, but should evaluate all possible environments that may be relevant. We also should not assume that we will control the airspace over our air bases.

Fourth, systems analysis falls short of scientific research. There is very little chance of verifying the model or system except in very rare circumstances. Human judgment plays a role in an analysis and must be taken into consideration.

There is one other limitation which is peculiar to this study. There is no classified information included in this study, even though several classified sources are referenced in the bibliography. All information on weapons systems capabilities and combat operational

results was obtained from publications in the public domain. A result of the use of these sources may be that some of the data or information is limited in that it does not reflect the latest technological or tactical developments.

The next chapter discusses the problem of measuring the level of effectiveness of aircrew training systems, and presents an approach which could be used to determine periodic aircrew training requirements using different methods of training.

Chapter II

OBJECTIVES AND MEASURES OF AIRCREW TRAINING

Introduction

Ten years ago, General G. P. Disosway in discussing the future of tactical airpower noted that the basic strength of the tactical air forces depended on the numbers and types of aircraft available. He emphasized, however, that the aircraft are only as effective as the aircrews:

> The tactical fighter aircrew is the key element in the effectiveness of the tactical air forces. As such. his training must be conducted on a continuing realistic basis in order to maintain the highest degree of operational readiness for the tactical air forces (Ref 11:11).

Measuring the effectiveness of the tactical air forces in peacetime is difficult. The objective of this chapter is to shed some light on the problems associated with peacetime measurement of the effectiveness of the tactical air forces and the tactical fighter aircrews.

Defining the Objectives

Before performing an analysis of tactical aircrew training systems it is necessary to explicitly define the goals or objectives of the tactical air forces and of the tactical aircrew training. It is also desirable to be able to determine the degree of goal accomplishment for each alternative method of aircrew training.

Air Force Manual 2-1, which contains the doctrine for tactical air operations, states that the tactical air forces ". . . are organized, equipped, and trained to conduct sustained air operations aimed at the destruction or neutralization of enemy forces" (Ref 2 :1-1). In discussing the effectiveness of the employment of the tactical air forces, the manual defines one measure of employment effectiveness as the ". . . degree of destruction inflicted upon the enemy . . ." and noted that the final measure is the degree to which the destruction or neutralization contributes to the ". . . achievement of joint force command and national objectives" (Ref 2:4-2).

In peacetime, it is difficult to measure the degree of destruction or neutralization that might be required to fulfill the tactical air force combat mission as stated above. It seems that the goal or objective of the tactical air force commanders should be to be able at any time to employ combat ready aircrews and units to accomplish destruction or neutralization of the enemy through sustained air operations. Intuitively, it is apparent that the degree of destruction inflicted upon the enemy is dependent upon the particular enemy in question, the environment at the time of the operations, and many other unpredictable and nonquantifiable factors. Destruction of some future enemy in an unknown environment is an example of an unbounded objective (e.g., How much destruction? At the cost of how many weapons systems?). The question of what cost in resources (e.g., material, personnel, or dollars) is acceptable for the required destruction or neutralization is not addressed, although the requirement to be able to conduct sustained air operations implies that the factor of attrition be taken into consideration.

The difficulty in determining the precise objective of the tactical air forces affects the determination of the objectives or goals of peacetime tactical aircrew training. How do you define the aircrew training objectives with an unbounded objective of the tactical air forces? In many matters of defense policy, the objectives may not be generally agreed on by the policy makers. When this is the case, the choice may be said to be between the objectives, not between the alternatives (Ref 31:8). To avoid this dilemma and in order to proceed with a meaningful analysis of alternative aircrew training systems, the objective of tactical aircrew training is defined as the maintenance of a level of aircrew and unit combat readiness such that the tactical air forces are capable of conducting sustained air operations to aid in achieving national objectives.

The only realistic bound which can be applied to this objective is a lower bound. That is, the tactical air forces must be at least at this stated level of combat readiness, however it may be measured. Any higher level of combat readiness may be inefficient and a waste of resources in peacetime, but any lesser level can be disastrous in a national emergency. Any tactical aircrew training system should satisfy the ultimate criterion of maintaining tactical aircrew combat readiness such that the objective of the tactical air forces can be achieved.

Aircrew Continuation Training

The word aircrew, as used in this study, refers to the two man aircrew of the F-4 aircraft. Individual members of an aircrew will be identified either as the pilot, the rear seat aircrew member, or

aircrew member (when it could be either). The rear seat aircrew member is a rated navigator who has been trained to operate the F-4 weapons systems and he is often referred to as the weapons systems operator (WSO).

Training may be defined as the act of instructing so as to make proficient. In the Air Force it may be defined as that work required to maintain individual and unit proficiency. The largest portion of the actual work of tactical aircrew continuation training is planned and accomplished by the aircrew members themselves.

Aircrew continuation training may be accomplished while airborne, in various types of ground based simulators, or during formal classroom training sessions. This study will concentrate on the airborne aircrew continuation training. Airborne continuation training in the air-to-ground weapons delivery area is accomplished on so-called weapons ranges. The different types of weapons ranges applicable to this study are classified and discussed in Appendix A of this study.

Measures of Aircrew Training

The key element of effective aircrew continuation training is the possession of the capability to measure the training. There are a number of measures of airborne training accomplishment presently in use in some form in the tactical air forces. These include:

1. Flight hours. This is the amount of flying time that is logged in the aircraft flight record. This measure is used by all Air Force aircrews to comply with the USAF minimum flying time requirements.

2. Flying sorties. The sortie is normally one flight performed by an aircrew, but it is possible to accomplish more than one training sortie on a single flight. For example, an air refueling may be accomplished enroute to a bombing range. This would be logged as a training sortie for the air refueling requirement and a training sortie for the bombing training.

3. First pass across the target. Normally, there can be only one "first pass" per type of weapon delivery per sortie. This is an attempt to measure how the aircrew would perform if they were allowed only one pass against a hostile target.

4. Engagements. This measure is normally used with air-to-air combat training missions. The engagement generally is defined as an encounter between adversaries until it is terminated by the airborne commander of the flight. More than one engagement is normally accomplished on a sortie.

5. Qualification events. In weapons delivery training the aircrew is required periodically to employ the training weapons such that he meets established criteria for "qualification." Maintenance of this qualification is necessary in order to maintain the combat ready status of the aircrew (Ref 4:1-1).

6. Training events. This is the lowest common denominator of aircrew training. A valid training event may be a sortie (e.g., air refueling); an engagement (e.g., air-to-air); first pass (e.g., nuclear weapons delivery); or any qualification event. More than one event may be accomplished on one sortie. For instance, a single normal bombing training sortie may enable the aircrew to accomplish a high angle dive bomb event, a low angle bomb event,

an air-to-ground rocket event, and a strafe event. These events do not necessarily have to be "qualifying" in order to be credited against the aircrew periodic training requirements.

Presently, the measure of aircrew continuation training most universally used is that of numbers of valid training events accomplished by the aircrew. A statistical record of these events is maintained over training periods of six months. During each six month period, each aircrew is required to accomplish a certain number of each event to maintain his Phase III (combat ready) status (Ref 4:1-2).

The continuation training requirements are established jointly by the three tactical commands (PACAF, TAC, and USAFE) and are supplemented by each command to meet particular mission requirements. These training requirements are minimum requirements and each commander has the authority and the responsibility to require more of individual aircrews to insure that they attain an acceptable level of proficiency (Ref 38:26).

Measures of Effectiveness of Aircrew Training

Regardless of the measure used, the USAF requirement is that the training must be <u>effective</u>. This point was emphasized in a recent issue of <u>TIG Brief</u>:

> Any Air Force organization is only as good as its level of proficiency--attained and maintained through an effective training program. In this age of ultra-sophisticated weapon systems, only a highly trained individual can handle them effectively. Anything less than an effective training program is not only a waste of Air Force money, but a serious USAF deficiency (Ref 12:1).

Objective measurement of the effectiveness of aircrew training is

difficult. Evaluation of aircrew training effectiveness is dependent upon the quality of the method of measurement and the assessment of aircrew performance with regard to that measure (Ref 35:112). In the past, the measures of the performance level that aircrews must achieve have been established on the basis of experience and expertise on the part of the policy makers. There is a possibility, however, that they may not be set correctly this way (Ref 35:190). If the measure is too low, the effectiveness of the tactical air force is degraded and may be misrepresented. If the measure is too high, the result may be costly over training; perhaps at the expense of proficiency in another tactical area.

In all military training systems the ultimate criterion of training effectiveness should be stated in terms of effectiveness in a combat situation. In peacetime it is necessary to select an actual criterion which is only an approximation of the ultimate one. Since most aircrew training has been accomplished during peacetime, evaluation of training effectiveness (or aircrew proficiency) has been made upon approximate criteria rather than upon ultimate criteria. To insure that the measures of aircrew proficiency obtained in peacetime are useful, it should be required that the criteria developed and used are good approximations of the ultimate criteria. A good criterion for measurement of aircrew proficiency is said to be one that is both reliable and relevant (Ref 36:22).

Reliability of a criterion for measurement of aircrew proficiency means that the actual combat readiness level for one aircrew is near the actual level for another aircrew if both have been measured to be equal using the approximate criteria. Reliability of a criterion for

measurement of aircrew proficiency also indicates that the desired level of combat readiness does not change appreciably over a period of time.

It is very difficult to measure the relevance of a criterion for the measurement of tactical aircrew proficiency. One method might be to allow different aircrews (who have been determined to be combat ready by some means of measurement) to expend weapons against a realistic target and note the effectiveness of their weapons against the target. If the results were as predicted then the measure of combat readiness used for those aircrews might be considered as being relevant to the ultimate criterion.

Measure of Aircrew Bombing Proficiency

When discussing measures of aircrew proficiency for employment of air-to-ground weapons, almost all practitioners refer to circular error average (CEA) or circular error probable (CEP). The first measure, CEA, is simply the mathematical mean of all scored weapon impacts about a given aim point or series of aim points. The CEA can be calculated and stated as that of an individual, a flight, a squadron, or a wing. The CEP measure refers to the radius of a circle that encompasses fifty per cent of bomb weapons impacts. These measures reflect long standing beliefs about what should be required of an aircrew with various kinds of weapons. As an example, the aircrew must be able to attain a 140 foot CEA to qualify in high angle (45 degree) dive bombing with ballistic iron bombs. This implies that, on the average, the aircrew may be expected to deliver a weapon no more than 140 feet from the desired target. With conventional iron bombs against point targets (e.g., an anti-

aircraft weapon emplacement) it is doubtful that even a hundred foot miss would have any lasting destructive effects on the targets.

It has been suggested by some laser experienced tactical aircrews that the level of an aircrew's competence in the employment of laser guided bombs should be evaluated by the use of the CEA measure. For instance, a CEA of 750 feet or less might be acceptable if ballistic practice bombs were dropped to simulate laser guided bombs. This CEA would have to be based on an assumed correction that the laser guidance unit could make to correct the bomb to impact on the target if it had been released in the basket. In other words, if an actual laser guided bomb had been released, it would have corrected the 750 feet or less to the target. One feasible method of establishing an aircrew proficiency measure by use of the CEA is presented in Appendix B of this study.

A Cost Effectiveness Approach

Choice of an aircrew training system should not be based on either cost or effectiveness alone. Both cost and effectiveness must be considered simultaneously in relation to each other (Ref 17:50). To fix one and ignore the other could be inefficient at best or ineffective at worse. The amount of tactical aircrew training required should be balanced with the resources available for maintaining the entire tactical air forces combat readiness.

Comparison and evaluation of unlike alternative systems generally can be approached by one of the following two methods. The first is to fix a level of effectiveness or performance and determine how much it "costs" for each system to meet this standard level. The second method is to assume that an equal quantity of resources is available for the

investment and operation of each system and then determine which system provides the greatest output. This second method may be said to be "equal cost-varying effectiveness," while the first may be said to be "equal effectiveness-varying costs" (Ref 37:57).

The analysis in this study will be based on a fixed level of effectiveness approach where the necessary level of effectiveness is stated in terms of the mission requirements. All training systems identified in Chapter IV will be evaluated to determine if each can attain the desired effectiveness. This evaluation will be accomplished with the aid of the data obtained from interviews conducted with laser experienced aircrews. The resources required to reach this level of effectiveness will then be measured for cost comparison. An approach of this type should allow accomplishment of a systematic, meaningful comparison of the alternative training systems.

Defining the Combat Readiness Level

There is a tendency to measure what a military system can do rather than what it should do (Ref 32:349). It may be easy to use the number of sorties flown during a training period or the number of bombs expended against a target as a measure when, perhaps, the effect of the sorties or bombs should be judged against what is required to achieve the objective of that military system.

Regardless of which method or means of measurement of aircrew training is used, the central issue is whether the aircrews are combat ready. In a peacetime environment, however, combat readiness may need to be modified to be something less than the level of actual combat readiness that aircrews attain after several months of combat. The

amount of resources required to maintain this latter level of actual combat readiness will not be available for peacetime continuation training.

Today, the combat readiness level of aircrews is measured by an inflight evaluation approach. It may be said to be an objective record based on subjective judgments by the individual making the evaluation. The aircrews are required to accomplish various written and oral examinations prior to the evaluation flight in the aircraft. In addition, the aircrews must successfully accomplish a flight simulator emergency procedures check. The inflight evaluation is accomplished by a highly qualified aircrew member designated on military orders who subjectively determines the combat readiness status of the aircrew. This evaluator, in turn, is evaluated periodically by command level evaluators to insure that the unit evaluators are as uniform as possible. Overall, this program has been reported to be practical in answering the basic question of whether or not an aircrew is combat ready (Ref 35:121).

The experience of the writer suggests that the person most likely to know the actual combat capability of an aircrew or of any size force is the immediate commander or operations officer of that aircrew or force. The ability to perform in combat effectively is not necessarily correlated to past performance within the limits of the present training measures criteria. An example of this would be the requirement to assist an Army unit with close air support under marginal weather conditions. Safety factors prohibit training missions to be flown under most marginal conditions and the person most likely to know if the aircrews would be able to complete the mission under such conditions would be the flight commander or operations officer in direct contact with

the aircrews.

The individual tactical air force commanders must rely upon their seasoned judgments of what should be reasonably required of their assigned aircrews and insure that they maintain this level of combat readiness. The responsibility for determination of each individual's combat ready status rests upon the immediate commander of that individual. Each commander evaluates his aircrews with his subjective assessment of aggressiveness, aerial leadership, self-confidence, discipline, flying ability, saftey awareness, etc. This assessment is no doubt unique to each commander and would be impossible to quantify objectively. It is the immediate commander's responsibility to provide combat ready aircrews and the writer maintains that, in the aggregate, this is done. This approach suggests that there is no "grey area" of combat readiness. Marginal aircrews (those that may be on the borderline of combat readiness) normally are not allowed to lead flying missions in combat or to assume other positions of aerial responsibility which may be above their capability.

Comparison of Training Systems to Combat

It is not clear as to the extent to which any particular training system is comparable to actual employment of tactical weapons in combat. It should be possible, however, to estimate the extent to which a training system will maintain an aircrew's combat ready status. The determination could be accomplished through various techniques to establish a trade-off relationship between use of each alternative training system and employment of real weapons in combat. By plotting the locus of all points which reflect an equivalent level of aircrew competence on an

ordinary, two dimensional graph, it is possible to visualize this trade-off process. Figure 2 presents the basic concept of this approach.

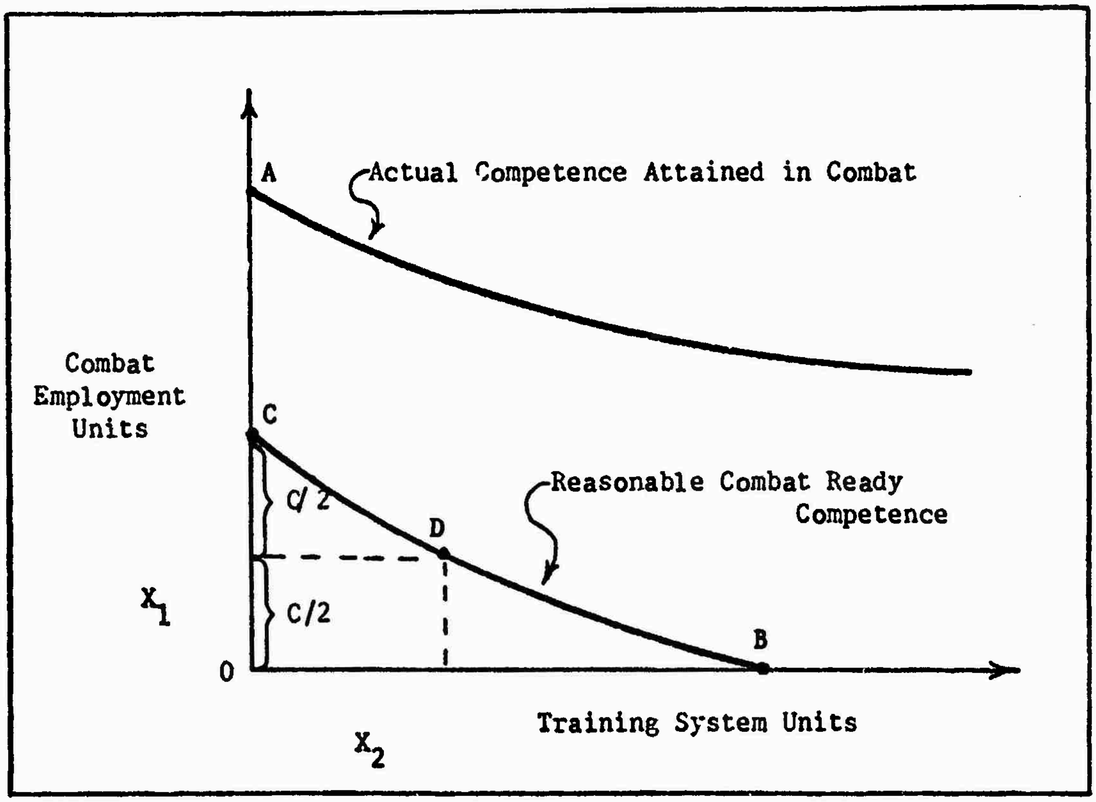

Figure 2. Hypothetical Trade-Off Between Actual Combat and an Alternative Training System.

This graph represents a hypothetical trade-off between employment of actual tactical weapons in combat and utilization of an aircrew training system. It should be measured over a period of time in order to provide a means of measuring the units on each axis. The units of measure of combat employment of a weapons system are plotted on the vertical axis, X_1. This might be measured as the number of combat sorties. The higher intercept on this axis, Point A, implies a certain level of competence that the aircrew would possess if they were employing the actual weapons in combat on a daily basis. The value on the vertical axis at Point C reflects the number of units of combat employment of the actual

weapons which may be subjectively determined to imply an acceptable level of aircrew competence. This level is defined to be that of combat readiness. The horizontal axis, X_2, reflects the units of measure of an alternative training system. These units may be sorties, simulator hours, or numbers of training munitions expended.

The objective is to determine the extent of training required to achieve a given level of aircrew competence. This may be accomplished by the use of experts skilled in the combat employment of tactical weapons. First, each expert should be requested to estimate the number of units of actual combat (such as sorties or firing passes) that he considers necessary to maintain a reasonable level of aircrew competence for employment of the weapons. On the graph in Figure 2 this is plotted as Point C. After this point is estimated, each expert should be requested to determine the number of units of the training system that he would require to maintain the same level of aircrew competence if the number of combat employment units were reduced from Point C to zero. The value obtained from this question would be plotted similar to Point B in Figure 2. The point on the X_2 axis would simulate a peacetime situation where the experts would not be allowed to train by use of any weapons employed in combat.

It would be desirable to obtain at least one more point between Point C and Point B to determine if there is a constant rate of substitution between the combat employment and the training system. The location might be estimated by informing each expert that he can only have half of the C units of combat employment and asking him how many training units he would require to maintain the same level of aircrew competence. In Figure 2 this is represented as Point D.

Since each expert will be likely to have different ideas of what value the C intercept should be, it will be necessary to establish some constraints. For example, they could be given a situation where they have many tactical responsibilities other than employment of the particular weapon in question. This is the situation that will probably exist in peacetime where one unit may be tasked with maintaining combat readiness in several types of missions. This should insure that the responses are relatively close to one another. The final results from the experts will likely be varied and it may be necessary to utilize some other method to arrive at a single value for Point B. One such method is the Delphi technique. This technique may enable an analyst to objectively measure subjective inputs from experts in the field (Ref 29:9). A discussion of the Delphi technique is presented in Appendix C.

A curve which connects the three points--A, B, and C--may be called an "iso-competence" curve of level "C." This name implies that any point on this curve represents a mix of combat employment of the actual weapons and use of the training system which may be expected to yield a level of aircrew competence equivalent to the C intercept on the X_1 axis.

A curve may likewise be plotted for the level of competence, "A," as illustrated in Figure 2. It is unlikely that any training system would be so effective that an iso-competence curve at the actual level of competence attained in combat would intercept the horizontal axis. An iso-competence curve at the combat ready level of competence should intersect the horizontal axis for any feasible training system. There may be some training systems which do not, however, do the latter. For instance, if the training system under consideration were a static, ground-based, weapons delivery simulator, it is unlikely that it would

singularly enable the aircrew to achieve and maintain readiness. If this were the case, the iso-competence curve would become asymptotic to a horizontal line somewhat above the horizontal axis as illustrated by the line X_1* in Figure 3. On the graph, this would imply that an aircrew could not maintain combat ready status with that system alone and thus, the system does not meet the combat readiness criterion.

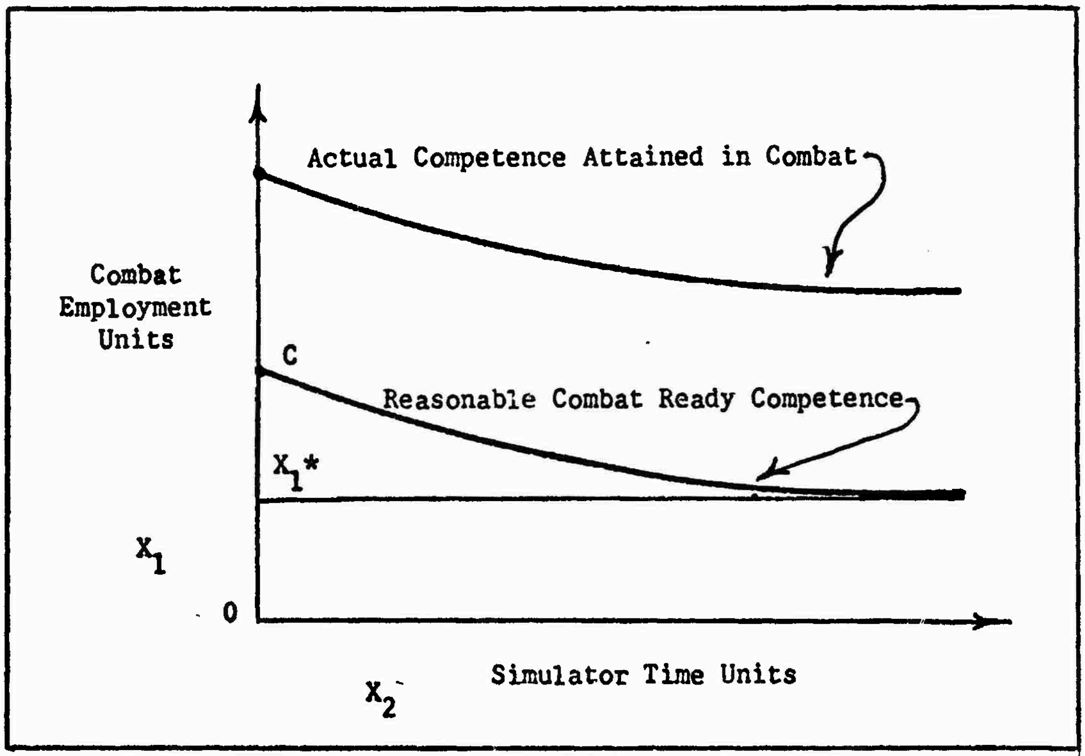

Figure 3. Hypothetical Trade-Off Between Actual Combat Weapons Employment and a Weapons Delivery Simulator.

Movement along the curve formed by connecting the points of equal competence may be said to be an application of the general economic law of diminishing marginal returns which states that as one system or input is substituted for another, with the competence level held constant, the conditions on which the substitution can be made will become less and less favorable (Ref 18:362). In other words, the more you have of any

training system, the less you tend to value another unit of that same system. In Figure 3, as the iso-competence curve C approaches the horizontal line X_1*, the number of units of simulator time required to replace one more unit of combat employment becomes infinite. The effect of this may be observed by noting that the slope of the curve becomes flatter as the input of the training system is increased and the input of actual combat employment is decreased.

The fact that a training system does not meet the combat readiness criterion does not necessarily exclude that particular system from consideration. It may complement another system which does meet the combat readiness criterion such that some combination of the two will be more desirable to the decision maker. An example of this would be a combination of training with inert laser guided bombs (subjectively determined to pass the combat readiness criterion) and training with a weapons delivery simulator (determined by subjective means to not meet the combat readiness criterion). It should be possible through the use of experts in a tactical training field to subjectively determine the number of hours of simulator training required to replace the dropping of one inert bomb while maintaining the same level of combat competence.

If Figure 4 on the next page were a graph of this hypothetical trade-off between the two systems, then a feasible point to start this trade-off would be at the value C on the X_1 axis. By subjectively determining the number of hours of simulator required to replace each inert bomb, it should be possible to establish points to aid in sketching an iso-competence such as shown in Figure 4. The estimated number of inert bombs expended is plotted on the vertical axis X_1, and the number of units of weapons delivery simulator time is measured on the horizontal

axis X_2. Note that both axes are "peacetime" axes; that is, it is possible to conduct peacetime operations at any mix of the two training systems represented by a point on the graph. On the previous two figures peacetime operations were restricted to points on the X_2 axis. Plotting of the points should continue until the iso-competence curve becomes asymptotic to a horizontal line such as line X_1** in Figure 4. The X_1** value would be the minimum number of units of inert bombs acceptable regardless of the number of simulator units offered in exchange.

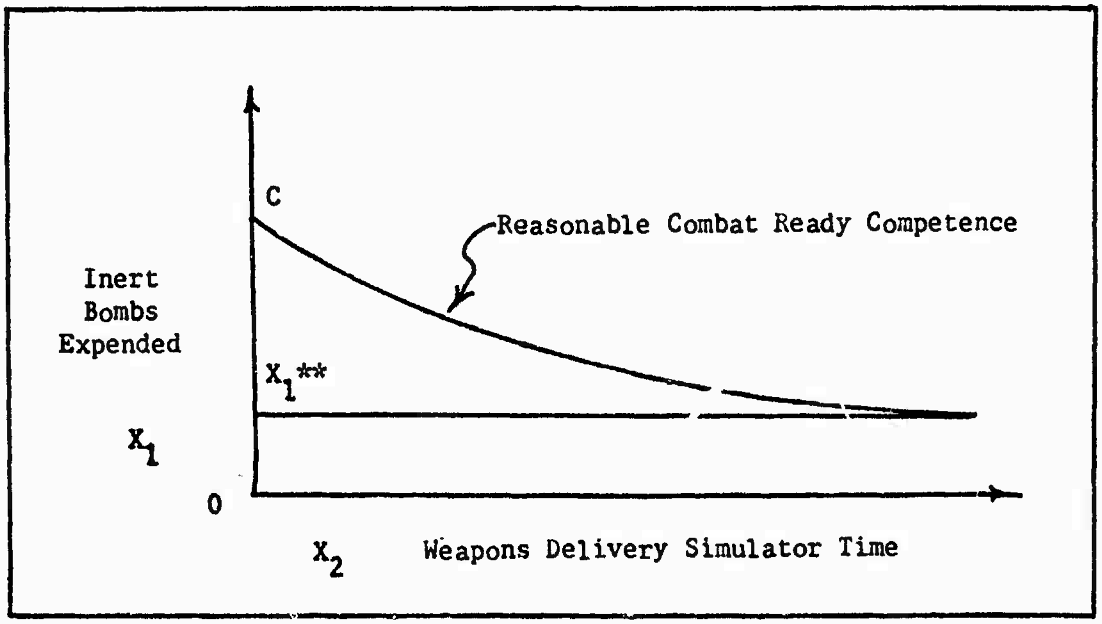

Figure 4. Hypothetical Trade-Off Between Inert Bombs and Weapons Delivery Simulator Time.

It may be possible to combine two or more training systems (which do not meet the combat readiness criterion by themselves) such that the combination of the training systems would produce an acceptable level of combat readiness. The graph in Figure 5 on the next page illustrates how a combination of two hypothetical training systems might be presented. A combination of three or more systems is difficult to picture on paper.

Again, experts would be required to subjectively determine what mixes of these systems would provide the desired level of combat readiness or competence. If all combinations of the systems under consideration are incapable (as subjectively determined by the experts) of maintaining combat readiness then it may be said that this particular mix of training systems is infeasible. When plotting the points representing the mixes of the two hypothetical systems in Figure 5, it should appear that the curve connecting these points is asymptotic to a line parallel to each axis.

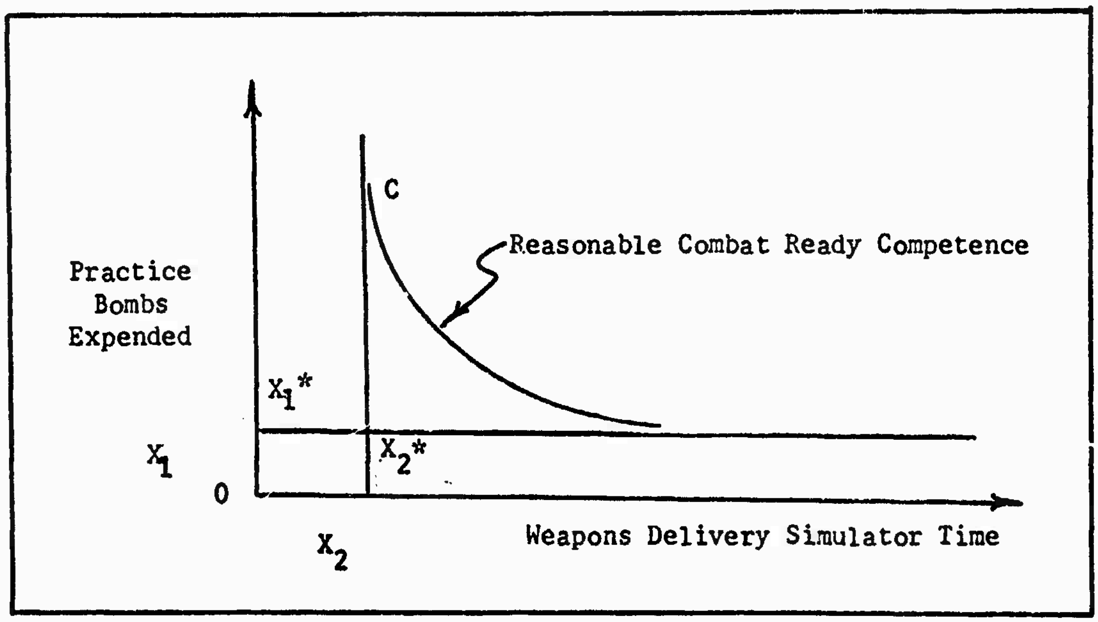

Figure 5. Hypothetical Trade-Off Between Practice Bombs and Weapons Delivery Simulator Time.

The presence of the asymptotes implies that X_2^* is the minimum number of units of simulator time required regardless of the number of practice bombs expended. Likewise, it follows that the horizontal asymptote at X_1^* implies that a minimum of X_1^* practice bombs will be required regardless of the number of units of simulator time offered in exchange.

Determining the Costs

It should be possible to determine the estimated costs required by each training system to maintain an acceptable level of combat readiness by the use of the trade-off approach in this chapter. For example, in Figure 2 the intercept on the X_2 axis, B, is the number of training system units required to maintain an acceptable level of combat readiness over a period of time in peacetime. When the number of training system units is determined for one aircrew, then it should be possible to calculate the estimated costs for the total tactical air forces if that system were selected.

Graphs such as those contained in Figure 4 and Figure 5 are also useful for cost effectiveness analyses. Each of the points on the reasonable combat ready competence curves will have costs associated with each mix of the systems represented by a point on the curves. By comparison of these costs, it should be possible to determine which of these combinations is least expensive. This optimal combination is then an efficient alternative training system which is estimated to meet the combat readiness criterion.

Summary

The objective of tactical aircrew training was defined as the maintenance of a level of aircrew and unit combat readiness such that the tactical air forces are capable of conducting sustained air operations to aid in achieving national objectives. This may be considered as an unbounded objective.

There are several measures of aircrew continuation training in use in the tactical air forces. The measure most commonly used is that of

numbers of valid training events accomplished by the aircrew. Regardless of the measure used, it is important that the aircrew training be effective. There are several measures of aircrew training effectiveness in use.

The individual commander of tactical aircrews and units is the individual most likely to know if the aircrews and tactical units are at a reasonable level of combat readiness. At the present time the tactical commander has sufficient latitude to insure that his forces are at a reasonable level of combat readiness.

By the use of subjective inputs from experts skilled in the combat employment of tactical weapons, it should be possible to estimate the amount of a training system which will be required to maintain a reasonable level of combat readiness. After this is done, it should be possible to estimate system costs such that a cost effectiveness analysis may be utilized for evaluation and comparison of alternative tactical aircrew training systems.

Chapter III

DETERMINATION OF CRITERIA

Introduction

Choosing the appropriate criteria for evaluation of a military aircrew training system is difficult. Research conducted by the writer in the field of criteria for evaluation of military training systems yielded no criterion that was clearly superior to the other criteria. The approach used in this study was adapted from a method used for developing criteria to be used for evaluation of measurements of aircrew proficiency.

The Major Criteria

There are two major criteria used in this study for comparison and evaluation of the alternative aircrew training systems. The first is that the system must be capable of maintaining an aircrew's combat readiness at a reasonable level. This is a subjective assessment of the capability of each system and, thus, it does not provide a rule or a standard which would allow ranking the alternatives in order of desirability or indicating the most promising. This ranking is necessary for a meaningful criterion for an analysis, such as this study, where all the alternatives are required to meet a minimum level of effectiveness (Ref 30:12). The second major criterion

is designed to fulfill this role of ranking the alternative training systems with regard to desirability of each of the systems. It is the criterion that the training system must be acceptable for use in the tactical air force units which may be tasked with combat employment of laser guided weapons. This criterion is actually an array of many sub-criteria, each of which serves as a tool for evaluation of the advantages and disadvantages of each proposed training system. This tool will help the decision maker to intelligently evaluate and rank the proposed systems in his personal order of desirability.

Each of the individual sub-criteria should be assigned relative weights for an analysis as they may overlap or be correlated with one another for certain systems. The following general rules may be useful when combining and ranking sub-criteria:

1. Sub-criteria should be weighted in accordance with their relevance to the ultimate criterion.

2. Sub-criteria which repeat or overlap factors in other sub-criteria should receive a low weight.

3. Other things being equal, the more reliable sub-criteria should be given greater weight (Ref 36:23).

The sub-criteria presented in this chapter have been arbitrarily weighted by the writer in their order of presentation with the first having the heaviest weight, the second the second heaviest weight, and so forth. This is accomplished for illustrative purposes.

The Sub-Criteria

The sub-criteria which are used for the measurement of the desirability of alternative training systems should be common to most

tactical aircrew training areas. The sub-criteria presented in this study were developed by the writer for specific application to evaluation of tactical aircrew training systems. The list of sub-criteria may not be completely comprehensive, but the purpose of the list is to point out that these sorts of factors should be considered when evaluating aircrew training systems.

Universality

The first sub-criterion is that of universality. A training system which is universally useable wherever tasked units are located is much more desirable than one which is limited in its use. All three fighter commands will likely be required to maintain some level of combat readiness with laser guided weapons. There will be little opportunity for long distance temporary duty for aircrews to train with a unique training system. Any training system procured should be adaptable for use in each general area of tactical operations.

The most desirable training system under this sub-criterion would likely be one that could be used in any tactical area with very little loss of training effectiveness. The least desirable would possibly be a system that could be used only at one location.

Combat Fidelity

The next sub-criterion is that of combat fidelity, or the accuracy of reproduction, of the actual combat environment. Complete fidelity may not be possible at all and the amount of resources required to maintain high fidelity may not be available. Each incremental increase in the combat fidelity of aircrew training should be evaluated

on a marginal cost effectiveness basis. In other words, is the increase in combat fidelity worth that many resources taken from some other area.

It is desirable that an aircrew training system be useable under conditions similar to those conditions found in combat. A training system which will accept the following factors will improve the combat fidelity of aircrew continuation training.

1. Tactical target acquisition (TTA). Most actual tactical targets are ill-defined and difficult to discern from the air. Indeed, if the enemy knows that they are targets, they will be camouflaged. The aircrew should be able to practice the elements which are essential for effective tactical weapons delivery which include: visual search, assimilation of available target information, detection and identification of the target, manipulation of the weapons controls, and control of the aircraft. The type of target (e.g., moving vehicle, cave, bridge, gun position) should vary from pass to pass or mission to mission so that the laser designator aircrew may practice the proper technique for illumination of each type of target. In the same vein, the aircrews should be able to use all applicable tactics and be able to attack from any direction. Most tactical weapons ranges are assumed to allow aircrews the opportunity to practice the above elements and techniques. For these reasons, a training system which could be used on a realistic tactical weapons range might be preferred to one that could only be used on a limited weapons range.

2. Combat strike force practice (CSFP). A tactical air force normally is more effective in a so-called "high threat" area

when employed as a coordinated combat strike force. This concept assigns various concurrent responsibilites (e.g., SAM neutralization, flak suppression, air cover, target destruction) explicitly to individual flights within the strike force. Effective control and leadership of this force is difficult as the combat environment demands close control and coordination of all members of the strike force. Extensive training is required to master the critical leadership required for effective employment of the combat strike force. A training system for weapons employment should allow strike force mission profiles to be flown without loss of weapons delivery training effectiveness. It is also desirable that the training system be operable on an electronic warfare range, especially if the electronic warfare range is co-located with a tactical weapons range. The electronic warfare range is discussed in Appendix A of this study.

3. Combat weight maneuvering (CWM). Actual combat operations require that the aircraft be utilized economically. For this reason, normal combat missions carry the maximum weapons allowed on the aircraft. The result is an aircraft much heavier than one on normal training missions (e.g., about 8,000 pounds heavier for the F-4). This additional weight affects the handling properties and lowers the margin of safety during the take-off, all flight activities, and landing (if the weapons are retained). To maintain a reasonable level of aircrew competence it is desirable to occasionally practice heavy eight operations. A training system which would allow this practice would probably be preferred to one that did not.

Reliability

The third of the sub-criteria is that of reliability of the training system. Reliability of a training system is meant to indicate that the system may be relied on whenever it is utilized. The training system should have high reliability to minimize the number of aircraft training sorties which are ineffective due to malfunctions and failures of components of the training system. Any aircrew training system should be capable of accurately tracing malfunctions and failures to the component at fault; whether the component is the weapon, the weapons release system, the laser designator system, the ground munitions or maintenance crew, the aircrew, or the ground based support and test equipment. The fault should be identifiable so that the aircrew may be made aware of why the system failed to operate normally. For example, a training system with a record of a large number of malfunctions of aircraft mounted components could be undesirable if the malfunctions could not be duplicated on the ground after the malfunctioning flights.

The aircrew training system should provide conclusive results and valid data on aircrew performance. If the results are in doubt or if the performance feedback is indeterminate, then it is difficult to measure the contribution that the training system made toward maintaining an aircrew's combat readiness. The level of reliability of tactical aircraft systems seems to be dependent upon frequency of use. That is, if the system is not exercised frequently, then the reliability of the system when called on to perform is likely to be low. All weapons release systems should be exercised frequently and equally to insure that they have an acceptable level of reliability when needed.

Timeliness of Data

The fourth of the sub-criteria is the measure of the timeliness of the actual aircrew performance data. Timeliness refers to the amount of time that the training system requires to compute and transmit weapons impact data to the aircrew. If the training system allows the aircrew more than one attempt against a target on one sortie, the effectiveness of the training system would be improved if the target miss distance or similar information were provided to the aircrew after each attempt. Normally, the uncontrollable factors which affect the impact point of a bomb are the same during a mission. These uncontrollable factors include the wind effects and the inherent instrument errors. If the impact points were known then the aircrew may be able to determine the reason for any deviations from the desired aim point. For these reasons, the aircrew and weapon scoring should be real time if possible. In no case should the scoring data be provided later than the post flight "debriefing" where the events of the flight are reviewed for lessons learned and deviations noted.

Flexibility

The training system should not be too dependent upon one or two elements or critical components. The sub-criterion of flexibility of the training system is meant to indicate that if a critical component of the training system fails then there should be sufficient back up capability to accomplish an effective training mission. It may be that if expenditure of laser guided bombs can not be accomplished, then some other type of weapons delivery mission can be attempted.

The same flexibility should apply when the training flight is unable to enter the weapons range for reasons not related to failure of the training system components. For example, a weapons range may be closed due to marginal weather conditions while the training flight is enroute to the range. It is desirable to have the capability to accomplish an alternate training mission such as air-to-air intercepts.

Other various reasons for not having access to a weapons range include inoperative radio equipment on the weapons range, malfunction of range scoring systems, pre-emption of the range by other users with higher precedence (e.g., in Europe, USAFE can use some ranges only on an "as available" basis), and weapons systems discrepancies which are detected while enroute to the weapons range that prevent safe expenditure of training weapons.

Switchology

Correct selection and proper manipulation of the various aircraft switches and controls is essential for effective weapons employment. The term "switchology" has evolved to indicate the selection and manipulation of these switches and controls. In order to minimize the possibility of an aircrew switchology error in combat, the training system should have a very high switchology fidelity with the actual weapons release system.. Adherence to this principle in the development of training systems will also reduce the possibility of aircrew switchology errors in the peacetime environment. Switchology errors in peacetime operations often result in release of training weapons over other than the desired target area.

Flying Safety

The designation of flying safety as the seventh sub-criterion by no means implies that safety of flight considerations should be placed this far down as a criterion for the evaluation of alternatives. Safety of flight considerations are foremost in all training operations. The term as used in this study refers to the restrictions to an alternative training system which are due to the necessary safety considerations. When flying safety is compromised, then both the quantity and the quality of aircrew training suffer. For example, a desired mission profile may include a rendezvous with a SAC tanker for air refueling, followed by a low level (500 hundred feet above ground level) navigation route to weapons range. This is a normal training mission which is planned to accomplish at least three different training events. If a component of a training system were suspended from the aircraft, it might be that safety considerations would prohibit any air refueling or low level operations outside of the weapons range boundries. This would decrease the desirability of this particular training system.

Availability

The amount of time required to post-flight, service, and preflight an aircraft for a second or third flight may be referred to as turn around time. The amount of normal ground maintenance and turn around time is very important in tactical operations where an aircraft is often scheduled to fly twice daily. Any training system which requires excessive safety checks and upload and download time may prevent use of the aircraft more than once per flying day. A training device

which is attached to normal weapons attachment locations on the aircraft may lengthen unscheduled maintenance time if the device has to be removed prior to the maintenance. The net effect of increased times of the above actions may increase the costs of a proposed training system, either by decreasing the rate of aircrew training or by requiring more investment in hardware and personnel.

System Life Factor

The system life factor should be evaluated for each component of a proposed training system. A component of a training system which is carried on the aircraft may be affected by excessive operating time or the high "G" dynamic loading of tactical flying operations. These factors may act to accelerate the "aging" of the component which would require maintenance or replacement of the component earlier than programmed. There may also be added costs of increased preventive maintenance requirements along with decreased training system availability. These adverse factors may require a larger investment in hardware and personnel in order to maintain the required rate of training.

Temporary Duty

A training system which requires frequent or extended TDY to accomplish continuation training may not be desirable from an aircrew scheduling perspective. There are many more costs associated with TDY than the travel and per diem costs. There is a cost in unit availability. The tactical fighter units are always susceptible to short- or no-notice unit deployments to overseas areas and frequent TDY for aircrew training

would reduce the number of tactical units available for immediate deployment. There is also a possibility that other TDY commitments may prevail over TDY required for training: for example, the ninety day or the 179 day TDY unit rotations to fulfill operational commitments in overseas theaters.

There is also a cost that affects personnel retention. Operations at other than home bases require TDY by many personnel in a tactical wing: maintenance, supply, security, food service, etc. In an all-volunteer Air Force, this may not be desirable due to personal hardships which often are aggravated by TDY.

Summary

There are two major criteria used in this study for evaluation of tactical aircrew training systems. The first is that the training system must be capable of maintaining aircrew combat readiness and the second is that the training system must be acceptable for use by the units in the tactical air forces tasked with the mission for which the training is required.

The second major criterion is composed of a number of sub-criteria, each of which offers a different means to evaluate a proposed aircrew training system. These sub-criteria may be used for ranking alternatives or for determining the desirability of each alternative. All of the sub-criteria described in this chapter will be applied to the alternative training systems which are determined to be capable of maintaining a reasonable level of aircrew combat readiness for the employment of laser guided weapons.

Chapter IV

IDENTIFICATION AND DEVELOPMENT OF ALTERNATIVES

Introduction

The objective of tactical aircrew training is to maintain a desired level of aircrew and unit combat readiness. Each feasible alternative method or system which could possibly accomplish this task should be identified and evaluated. This chapter will present the relevant components of laser guided bombing systems, discuss certain critical factors of tactical weapons systems, and identify each alternative training system that will be examined in this study.

Laser Designator Systems

All laser guided weapons require some member of the attacking force to illuminate the target with sufficient laser energy such that the weapon will be guided to the target. The laser designators may be located on the aircraft delivering the weapon, on an aircraft which is flying in formation with the bombing aircraft, on an aircraft assigned the task of illuminating the target for a host of other bombing aircraft, or with friendly personnel on the ground with a direct line of sight to the target. The roles of these designators are referred to as <u>self-contained</u>, <u>wingman delivery</u>, <u>hunter-killer</u>, and <u>ground forward air controller</u>, respectively. Since each of these roles requires different

techniques of aerial coordination and laser designation, each requires different approaches to practice. The role of the designator on the ground is assumed to be filled by personnel other than aircrews and thus it will not be evaluated in this study. The wingman delivery role will be considered as a part of the hunter-killer role for the purpose of this study.

There may be a requirement in the near future for the aircrews to be able to identify lasers with some sort of coding arrangement. This coding would be necessary when numerous laser designators are in use simultaneously in a small area. The bombing aircrew would thus need to be able to determine which targets are illuminated by which laser designators (Ref 21:24). This may introduce another factor which will affect training requirements for employment of laser guided weapons.

The critical component in the delivery of all laser guided weapons is the laser designator system. These laser designator systems are relatively expensive and all that have been used thus far have required modification to the designator aircraft. The modification does not, however, preclude use of the aircraft in other roles. Three aerial designator systems are included in the scope of this study--the Paveway I, the Pave Knife, and the Pave Spike. It is likely that one or more of these three systems will be operational during the period covered by this study.

Paveway I

The first aerial tactical designator system used to provide laser energy for laser guided bombs was the Paveway I system, dubbed "Zot" by the aircrews who used it. This laser designator system was first used

in combat in Southeast Asia during 1968 (Ref 26:54).

The Paveway I laser designator was mounted on the left rear canopy rail of the F-4 aircraft which meant that the laser beam could only be aimed out of the left side of the aircraft. This position prevented use of the Paveway I in the self-contained role and restricted the extent of allowable evasive maneuvers which were available to the designator aircrews during the time of flight of the laser guided weapons.

Pave Knife

The follow-on to the Paveway I was the Pave Knife designator system. The Pave Knife system is a completely self-contained, pod-mounted laser designator system. Self-contained means that it may be down-loaded from one designator aircraft and up-loaded on another. The designator aircraft have to be modified to accept the Pave Knife system. Pod-mounted means that it is mounted on a weapons attachment point on the bottom of the aircraft. This position increases its field-of-view substantially. The nose of the pod has a "dropped snout" appearance which allows a wide field-of-view laterally along with deep vertical viewing angles for the television camera and the laser designator (Ref 26:55).

By 1971, six of the Philco-Ford Pave Knife systems were in initial trials in Southeast Asia. The F-4 rear seat aircrew member is able to identify a target by use of the low light television in the Pave Knife and illuminate it with a laser beam. The designator aircraft may then assume the self-contained role or designate for a remotely released bomb (the hunter-killer or wingman delivery roles). The cost per unit of these first six systems was reported to be $550,000 (Ref 27:52).

The range of the Pave Knife system is reportedly in the area of three to seven or more miles (Ref 26:58). The rear seat aircrew member is able to keep the laser beam on the selected target by use of a hand control which positions both the television camera and the laser illuminator.

A possible improved version of this system is the Long Knife target acquisition and laser designator system which was recently reported in Aviation Week & Space Technology. This system apparently will work at standoff ranges of up to thirty miles with a tracking accuracy twice that of the Pave Knife system (Ref 15:41).

Pave Spike

The next improvement was the Pave Spike designator system. The Pave Spike system is a pod-mounted combination television and laser designator which permits the rear seat aircrew member in the F-4 to visually acquire and illuminate targets for laser guided weapons (Ref 15:41). The system also provides continuous angular position and range to the selected target. This information may be utilized for the self-contained, the wingman delivery, or the hunter-killer role. The rear seat aircrew member is able to continuously illuminate the target during escape maneuvers until bomb impact (Ref 41:4-1). Pave Spike is designed to accept either pilot visual aiding or the aircraft weapons release control system aiding of television acquisition (Ref 42:16).

In 1972, the per unit cost of a Pave Spike pod was stated to be \$120,000 (Ref 38:C-3). The initial \$3,850,000 of a \$39,000,000 contract was recently awarded to Westinghouse for production of the Pave Spike systems (Ref 15:41). The size of the Westinghouse contract indicates that the

Pave Spike system is likely to be the laser designator and acquisition system procured for general use in the tactical air forces.

Tactical Weapons Systems Critical Factors

With any tactical weapons system there are several critical factors that influence the effectiveness of weapons employment at a particular instance. One of these factors is the reliability of the weapon itself. Will the fuze arm and detonate properly? Will the case of the weapon fail structurally on impact with the target such that the full effect of the explosive force will not be produced? Will the weapon guide or track as it may have been designed to do? The reliability of the weapons will not be considered to be a factor that is influenced by aircrew training and thus it will not be evaluated in this study.

A second factor is that of the weapons release system of the aircraft. Modern tactical aircraft have many varied and complex weapons systems capabilities and there are many opportunities for faults to occur in these systems. These faults may result in delayed weapons release, weapons release outside the proper parameters, or no release at all. This factor will be considered indirectly as, in the past, these faults may have been caused by the aircrew and an effective aircrew training system may thus reduce their occurrence.

A third factor is that of the skill or competence of the bombing aircrew. The aircrew must position the aircraft such that the weapons are released within certain parameters of air speed, altitude, relative target bearing, and slant range to the target. This positioning is necessary in order for the weapons to arm properly and to be capable of hitting the target, while allowing the aircraft to escape the blast effects

of its own weapon. Maintenance of this skill at an acceptable level is an objective of the aircrew continuation training program.

A fourth critical factor is that of the quality of communication in the attacking force. This is most important in close air support (CAS) missions where friendly forces are in direct contact with the enemy and a forward air controller (FAC) is required to precisely identify the targets for the bombing aircrews. This factor is especially important in the effective employment of laser guided weapons in the hunter-killer role due to the fact that the correct target must be illuminated with sufficient laser energy during the time of flight of the weapon (ten to twenty seconds) for the weapon to guide to impact on the target. In other words, the designator aircrew must insure that they will be able to illuminate the target for this period of time before authorizing a bomber aircrew to expend weapons. Effective communication is enhanced by proper training and should be a by-product of a desirable training system.

A fifth factor is that of the complex uncertainty of the combat environment that the actual weapons will have to be employed in. It is difficult to predict correctly, even in an established combat theater, precisely what the environment will be around a particular target on a particular day. In training operations, highly-qualified combat-seasoned flight leaders are able to provide some level of realism of the atmosphere of a combat environment.

The skill of the designator may be considered as a sixth critical factor for employment of tactical laser guided weapons. This person may be on the ground, airborne in another aircraft, or be in the aircraft that is delivering the weapon. It is critical that this individual be

skilled in the use of his system. This dexterity is not achieved quickly. One aircrew member interviewed for this study who had been a squadron commander of a laser tasked unit observed that it often took two months in actual combat for a designator aircrew member to achieve optimum combat efficiency.

The last factor that is presented is that of the weather in the target area. Lasers can be employed on any target that a human eye can see, both in daylight and in darkness. However, the energy can not pass through clouds and thus alternate tactics must be used to attack and destroy targets in adverse weather conditions. This is a factor of tactics and thus it will not be discussed in this study.

Alternative Training Systems

Each of the alternative training systems is merely a possible means for achieving the goal of maintenance of the combat readiness of the tactical aircrews at a reasonable level. The systems may be utilized independently of each other, or in some cases, in conjunction with one another. The following approaches for aircrew training were identified after the interviews of the experts in the fields of aircrew training and laser guided weapons employment. Each approach to aircrew training, or method of aircrew training, was described to the laser experienced aircrew members for their subjective assessment of whether the approach was capable of maintaining aircrew combat readiness.

Practice Bomb in the Basket

The practice bomb in the basket approach requires expenditure of a common BDU-33 practice bomb against a scored target. The bomb will be judged to have been released within the "basket" of required parameters if its circular error is within a specified distance from the desired target. One study stated that this specified circular error should be 750 feet (Ref 38:24). This criterion implies that a laser guidance kit would have corrected any error up to 750 feet so that the bomb would have impacted on the target. The practice bombs are carried on the aircraft in a standard practice bomb dispenser.

Inert Laser Guided Bomb

The inert laser guided bomb approach requires expenditure of an actual laser guidance kit mounted on an inert, ballast filled bomb. Both of these components are in the Air Force inventory at this time. If the bomb is released in the basket and the target is properly illuminated by a laser energy source, then the bomb should impact on, or in close proximity to the target. The inert bomb could be carried on the bomb ejector racks used for carriage and release of the actual weapons.

Practice Laser Guided Bomb

A similar approach to the inert laser guided bomb approach requires expenditure of a practice bomb which has the capability to guide to impact on a laser designated target and which will have approximately the same release parameters as the real weapon. At the present time, there

is no bomb of this type in production, however, a prototype was recently designed and built by a student in the Graduate Air Weapons program at the Air Force Institute of Technology. This bomb consisted of a basic BDU-33 practice bomb with an inexpensive laser guidance unit mounted on it. Two of these bombs could be carried in the standard practice bomb dispenser (Ref 6). This prototype has undergone limited testing, but it has not yet been dropped from an airborne fighter aircraft. It is assumed for the purpose of this study that such a practice laser guided bomb is feasible and that it could be designed such that it could be employed within the same parameters as the actual laser guided weapon.

Video Tape Assessment

Laser designator systems normally provide a television presentation in the rear cockpit of the F-4 which the rear seat aircrew member uses to aim his laser beam. These systems have the capability of recording the video presentation on magnetic tape by the use of a video recorder mounted directly on the television viewer. It is possible to "playback" the video tape immediately after a flight and objectively determine the aim point of the laser and observe the actual recorded impact of the bomb if it is within the field of view of the television camera. The Pave Spike designator system will have this capability.

Laser Monitoring/Target Scoring Device

It is possible to build a small laser energy detection device which can be placed on a point target. When a pulse of laser energy of a certain intensity is detected on the target area the device will

flash a light bright enough so that it can be seen by the aircrews in the vicinity of the target. The device would be set for an intensity level high enough to provide reliable guidance for a laser guided weapon (Ref 13).

This device would be similar to the pulsed image converter system (PICS) developed by the Applied Physics Branch of the Air Development Test Center (ADTC) at Eglin AFB, Florida (Ref 38:24). The PICS is an expensive, unique, highly instrumented system designed for precise data collection which provides more data than that which would be practical for normal aircrew continuation training.

A reasonable design for laser monitoring and target scoring would require four detection devices monitoring small, mutually exclusive areas of a target. For example, over a 2500 square foot area each device might monitor a 625 square foot area sector. The devices could be mounted on poles in the center of each sector, suspended from overhead wires in each sector, or trained on their respective sectors from an adjacent location. In any case, a realistic target (e.g., a truck or a gun) could be in the center of the square area with no degradation of the monitoring devices. A power source would be required and could be installed in a small two wheel trailer. The system could be wholly self-contained in the trailer so that it could be moved easily from target to target on a weapons range (Ref 13). Conceptually, the laser monitoring and target scoring complex might appear as pictured in Figure 6 on the next page.

If a pulse of laser energy were detected in any area, it would cause the corresponding light to flash. To the aircrews, this flash would indicate that that particular sector was illuminated at that time.

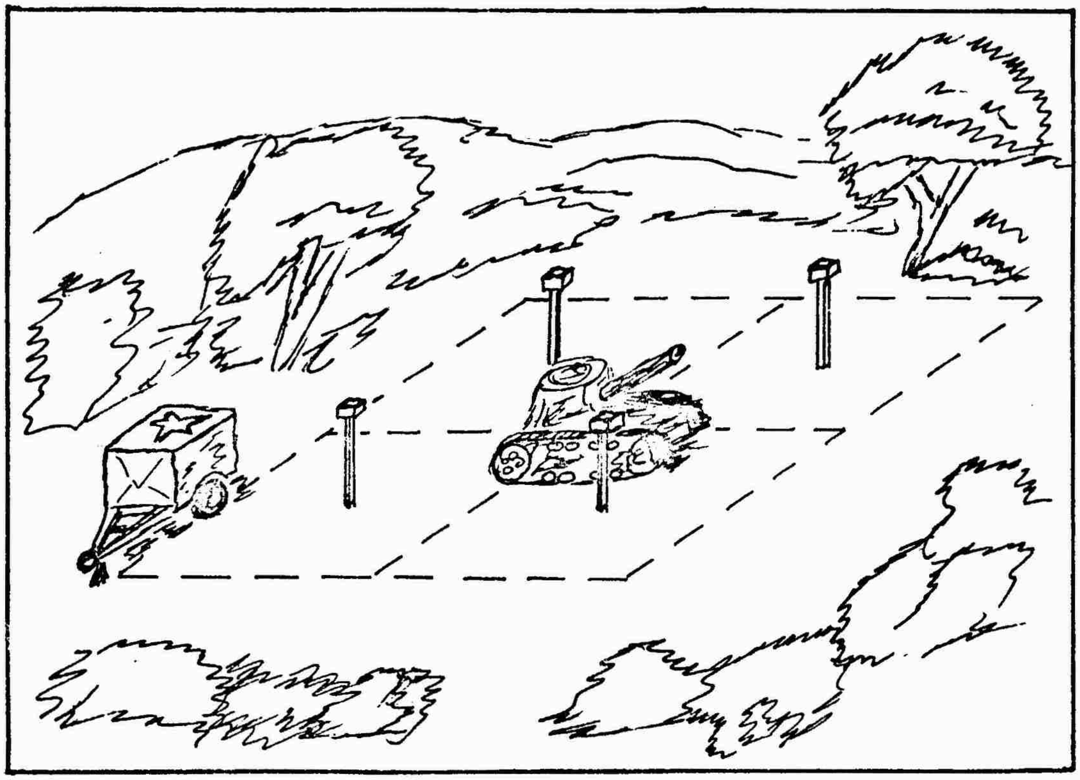

Figure 6. Typical Laser Monitoring/Target Scoring Complex.

If the laser beam illuminates the boundary of two sectors, then the two lights would flash. If the beam were detected at the center of the target area, then all four lights would flash (Ref 13).

Air Combat Maneuvering Range

The air combat maneuvering range (ACMR) is a sophisticated aerial tracking system which the contractor, Cubic Corporation, claims will provide ". . . real-time monitoring of aircraft position, flight dynamics, weapons status, and firing parameters" (Ref 9). This system is comprised of aircraft mounted airborne instrumentation sub-systems (AIS) that transmit data to tracking instrumentation sub-systems (TIS) stations, that, through a master TIS, relay by use of microwave data links to a control and computation sub-system (CCS). The CCS provides real-time

data via high quality data lines to display consoles at the display and debriefing subsystem (DDS) (Ref 9). Figure 7 on the next page illustrates the major elements of the air combat maneuvering range system. At the present time, one ACMR is installed at the U. S. Navy Yuma air-to-air range for air-to-air training purposes. The U. S. Air Force is considering installing an ACMR at Nellis AFB, Nevada (Ref 33).

The ACMR is said to be capable of providing accurate tracking information on four aircraft at one time. There is complete aircraft maneuvering freedom anywhere within the range airspace. The ACMR system provides real-time pseudo-three-dimension display of the aircraft in flight along with the terrain features below the aerial range. Simultaneous live mission and post mission evaluation is provided along with hard-copy output of any display throughout the mission on a selectable basis. This output is provided at the display and debriefing subsystems that may be located both at the CCS and at the air base where the training flight briefings are conducted (Ref 10:9-2).

Cubic Corporation states that only minor modifications are required to enable the ACMR system to function as an air-to-ground scoring system. These modifications include the addition of the capability to accurately calculate the altitude of aircraft below 5000 feet above ground level (Ref 10:9-3). For use as a laser guided weapon air-to-ground training system, it may be that the present coverage from 5000 feet above ground level up to 40,000 feet is adequate as most laser weapons delivery is accomplished above 5000 feet. The laser guided weapons are normally released at altitudes above 5000 feet above the ground and the aircraft may descend below 5000 feet after the weapon is falling toward the ground. At the altitudes above 5000 feet the control

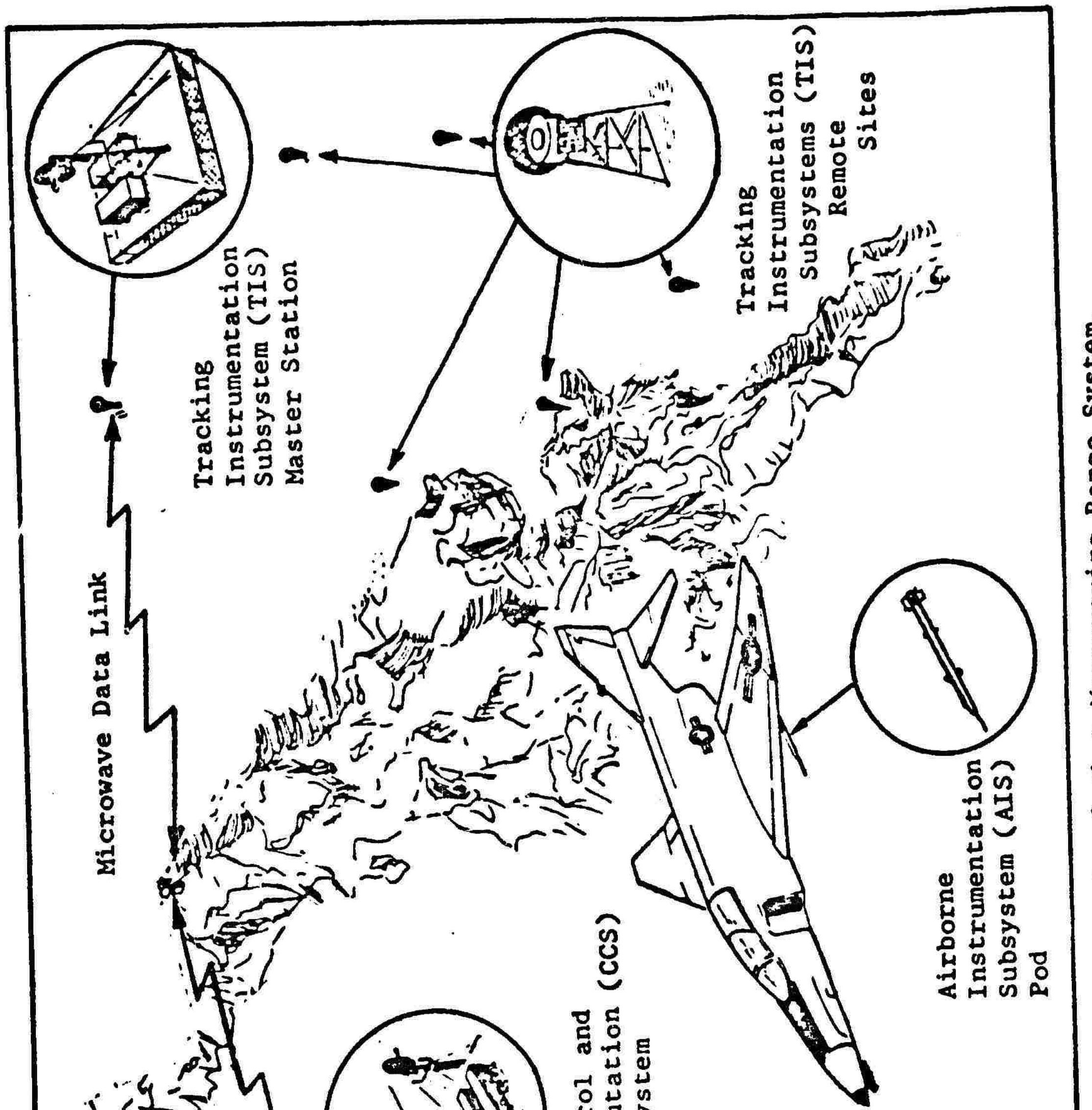

Figure 7. **The Major Elements of the Air Combat Maneuvering Range System.**

and computation sub-system may be able to predict the impact point given the aerodynamic characteristics of the simulated weapon and the data transmitted from the aircraft at the simulated release time.

Weapons Delivery Flight Simulator

Most of the aircrew members interviewed during the research conducted for determining the possible approaches for aircrew training acknowledged that the requirement exists for a weapons delivery flight simulator. The simulators available at this time are not programmed to be provided with the capability for conducting aircrew training for employment of laser guided weapons, insofar as the writer knows. It is possible that the simulator for air-to-air combat (SAAC) may be adapted for this purpose (Ref 23:8).

Any simulator that is used for aircrew training for laser guided weapons employment should, at the minimum, provide for initial training and evaluation of the basic tactics and techniques which are pertinent to laser guided weapons employment. One difficult factor to reproduce in a simulator is the factor of multi-aircraft operations and the aircrew members interviewed emphasized that this is an important factor in the effective employment of laser guided weapons.

Summary

There are four delivery roles in which laser guided weapons may be employed--self-contained, wingman delivery, hunter-killer, and the ground forward air controller. Each role requires different techniques, thus each requires different approaches for aircrew training.

There are three primary laser designator systems--the Paveway I, the Pave Knife, and the Pave Spike--included in the scope of this study. Of these three, the Pave Spike is likely to be the laser designator and acquisition system procured for general use in the near future for the tactical air forces.

Seven alternative approaches for training aircrews for effective employment of laser guided weapons were identified as the result of research and interviews. These seven approaches were: practice bomb in the basket, inert laser guided bomb, practice laser guided bomb, video tape assessment, laser monitoring/target scoring device, air combat maneuvering range, and the weapons delivery flight simulator. The evaluation of these seven approaches will be presented in Chapter V.

Chapter V

EVALUATION OF ALTERNATIVES

Introduction

This chapter contains a description of the five alternative training systems that will be evaluated in the remainder of this study. The suggested numbers of aircraft sorties and weapons required for each alternative training system are based principally on interviews with the fourteen aircrew members who personally had combat experience in one or more of the three laser designator systems which are discussed in Chapter IV--Paveway I, Pave Knife, and Pave Spike. The interviews were structured to obtain each aircrew member's evaluation of how much of each proposed training system would be required to maintain a reasonable level of combat readiness. Appendix D of this study presents the basic outline of the interviews. The writer subjectively compiled the rough data obtained from these interviews to provide the aircrew continuation requirements suggested in this chapter. It is not the intent of this study to imply that these are actually the number of sorties or weapons that should be required for training, but that the methodology used for obtaining them is valid.

Each aircrew member interviewed by the writer stated independently that the critical element in the effective employment of laser guided weapons is the skill of the two man designator aircrew. The primary

reason for this is that the techniques and tactics necessary for effective laser guided weapons employment are completely dependent upon a high level of illumination skill and aerial leadership of the designator aircrew. Errors induced by bomber aircrews (those who drop the bombs in the hunter-killer role) are correctable to a great extent by the laser guidance kit, while poor illumination of the target or ineffective aerial leadership will most likely produce a completely ineffective attack. For this reason, continuation training for the bomber aircrews will be taken to be supportive in nature to the continuation training for the designator aircrews. The suggested amounts of each alternative training system that are presented in this chapter reflect this priority of training for the designator aircrews.

The training systems presented are evaluated as "pure" systems. This means that each alternative training system is procured and utilized independently of the other alternative systems for continuation training for laser guided weapons employment.

Evaluation of the data obtained from the aircrew member interviews resulted in five of the seven methods of aircrew training described in Chapter IV as being considered to be capable of maintaining the desired level of combat readiness for the laser designator aircrews. The two methods that were determined not to be capable of maintaining this level were the weapons delivery flight simulator and the video tape assessment. This determination and evaluation were accomplished subjectively by the writer.

The weapons delivery flight simulator is discussed in the "Other Alternatives" sub-section of this chapter. The video tape assessment capability will be included as part of the Pave Spike acquisition and

laser designator system. For this reason, video tape assessment is taken to be a "given" in aircrew continuation training and will be implicitly included as part of each of the five alternative training systems presented in this chapter.

Inherent in each alternative training system should be an adequate ground training program on employment of laser guided weapons. This program would be conducted in conjunction with the presently required periodic weapons academic instruction and aircrew testing programs. Tactical weapons ground training programs are normally conducted at the squadron or wing level and the instructors are specially tasked personnel from flight operations and the munitions maintenance section. There should be little or no difference between the alternate training systems in the amount of time or other resources required for the ground training.

The Alternative Training Systems

Alternative System One

The first alternative training system that will be presented is a combination of dropping a BDU-33 practice bomb in the basket along with video tape assessment of the laser aim point. This system will be referred to as the "basket and video tape" or "BVT" system. The proficiency of the designator aircrews would be evaluated by the post flight viewing of the video tape. The proficiency of the bomber aircrews would be evaluated by measuring their CEA against the established CEA that is required for that particular weapon. This method of training is basically in existence at this time and only a minimal amount of

effort would be required to initiate it worldwide when the Pave Spike system is operational and in the inventory.

The consensus of the interviewed aircrew members was that a minimum of six self-contained sorties and ten hunter-killer sorties should be accomplished each six months in order for the laser designator aircrews to maintain a reasonable combat readiness level using only this method of training. This combination would total sixteen sorties for each designator aircrew per six month training period. An estimated minimum of four BDU-33's would be expended by each aircrew on each sortie with the possible exception of the multi-aircraft hunter-killer missions where the employment tactics may allow only two or three "hot" ordnance release passes per aircrew.

Alternative System Two

The second alternative training system to be presented involves expenditure of actual laser guidance kits mounted on inert, real bombs. This system will be referred to as the "laser guided bomb" or "LGB" system. Video tape assessment would provide a means for measurement of the laser guided inert bomb impact points. The laser guidance kits and the inert bombs are presently in the inventory. Due to the relatively high cost of the laser seeker and guidance kits (about $3000), no aircrew member interviewed suggested that an actual laser guided inert bomb should be expended on every training sortie.

The aircrew members believed that it would be acceptable to mix "dry" training missions, where no ordnance is expended, with missions where the laser guided inert bombs are expended. Video tape assessment should be used to evaluate designator skill on those missions where no

ordnance was expended. Based on the interviews, it is suggested that a minimum of two laser guided inert bombs should be dropped by each aircrew per six months to compensate for dry training missions. The laser designator aircrews will expend the laser guided inert bombs on the self-contained missions and the bomber aircrews will expend on the hunter-killer missions. Using this scheme, there would be adequate opportunities for each designator aircrew to illuminate for two or three of the hunter-killer bombs in addition to their two self-contained bombs.

If this were the only available method of aircrew training, then the total requirement was estimated to be fourteen sorties per six months for each designator aircrew. The aircrew members estimated that six of these sorties would be flown in the self-contained role and the eight remaining sorties would be flown in the hunter-killer role. Both bomber and designator aircrews should be required to expend two effective laser guided inert bombs per six month training period. Effective in this sense is defined as a laser guided inert bomb that is dropped within the basket and that guided properly. Some aircrews may have to drop more than two laser guided inert bombs due to the possibility of bombs that are "no guides." Normally, no more than one bomb would be carried by an aircraft on any one sortie.

Alternative System Three

The third alternative training system is based on use of practice laser guided bombs. To distinguish this alternative from the alternative just discussed, this one will be referred to as the "practice laser guided bomb" or "PLGB" system. An operational practice laser guided bomb has not

yet been acquired by the Air Force. One prototype has been developed up through wind tunnel tests and, although not yet actually dropped from an airborne fighter aircraft, it may be indicative of the type of laser guided practice weapon which can be developed. It was assumed for the interviews that the cost of each PLGB would be no more than four hundred dollars.

In each six month training period, twelve training sorties were estimated to be required for each of the laser designator aircrews. The aircrew members interviewed suggested that four of these should be used in practicing the self-contained role and the remaining eight should be flown in practice of the hunter-killer role. One PLGB should be expended per sortie, while a second PLGB might be carried in reserve to expend if the first PLGB failed to guide.

Alternative System Four

The fourth alternative training system involves the use of movable laser monitoring/target scoring devices on the weapons range. These devices, including the flashing lights, would be positioned on the practice targets. It would not be practical to drop bombs which might destroy the monitoring and scoring devices, so no expenditure of bombs will be required. This method of training will be referred to as the "laser monitoring/target scoring" or "LMTS" system. The system is not yet in production, but an engineer who worked on the PICS stated that it should have a short development and initial production time span. The LMTS system could be designed to be moved easily and set up in a minimum amount of time by two personnel (Ref 13).

The interviewed aircrew members estimated that fourteen flying

sorties per six month period would be required for the designator aircrews using this method of training. Four of these would be in the self-contained role and the remaining ten would be in the hunter-killer role. No bombs of any type would be expended and video tape assessment would be an objective means of assessing laser designator aircrew skill as the flashing lights will be visible on the video tape.

Alternative System Five

The fifth alternative training system requires the use of a modified air combat maneuvering range. The modification would be to provide a capability of predicting air-to-ground weapons scores. This method of training assumes no laser operation is allowed and no weapons will be expended. However, both of these excluded elements may be combined with use of the air combat maneuvering range if the range is co-located over a laser cleared weapons range.

This method of training will be referred to as the "air combat maneuvering range" or "ACMR" system. Video tape assessment would be required to supplement the predicted impact points for measurement of aircrew proficiency. The spillover of the ACMR is significant in the areas of multi-aircraft missions, and it is likely that the system will be used for many more types of training other than laser guided weapons training (Ref 9).

Under the assumption that the ACMR system would be used as the only method of training aircrews for employment of laser guided weapons, the interviewed aircrew members estimated that a total of thirteen sorties per designator aircrew per six months would be required. Only two of these would be in the self-contained role and the remaining eleven would be in the hunter-killer role.

Other Alternatives

No aircrew member interviewed thought that any simulator that might be operational during this time period would be capable of maintaining a reasonable level of combat readiness for employment of laser guided weapons. For this reason no alternative which depends solely on use of a weapons delivery flight simulator will be evaluated in this study.

A flight simulator might be used in conjunction with the ground training with any of the five training systems noted above. Simulators are effective for laying the basic framework necessary to enhance crew coordination and to reduce switchology errors. They are also useful for evaluation of procedural proficiency of individual aircrews.

A simulator which could provide dynamic loads, or "G" forces, to the occupants would enable the rear seat occupant to practice aiming the laser beam during high "G" maneuvering flight. Presently, practice of this action can only be obtained in actual flight in an aircraft.

Another means of enhancing the effectiveness of designator aircrews training might be to provide movie film of actual camouflaged targets as they would be seen with the unaided eye in flight. The aircrews could be evaluated on their ability to detect, identify, and evaluate the targets and could be measured on the time required to do so. They also might be tasked to determine what they personally feel to be the most effective tactic to use to attack that particular target. The individual aircrew times and responses then could be compared to the norm which should be established for each film by laser guided weapons experts.

Still another possible method of aircrew training would be to connect a Pave Spike hand control to a bright, narrow beam flashlight

such that the hand control could control the light beam in a manner comparable in feel and response to the Pave Spike system. This device would be placed in a room where realistic film of targets (as seen through the Pave Spike system in a maneuvering aircraft) are projected on a screen. The designator aircrew would be able to practice target tracking with the flashlight "laser beam" by manipulation of the hand control.

These latter two methods of training were suggested by aircrew members during the personal interviews conducted by the writer at Eglin AFB, Florida.

Summary of the Alternative System Requirements

The designator aircrew continuation sortie requirements discussed above are summarized in Table I. This table is provided for ease of comparison of the five alternative training systems which will be evaluated in the remainder of this study.

Table I. Suggested Designator Aircrew Sortie Requirements per Six Months.

REQUIREMENTS	ALTERNATIVES				
	1 BVT	2 LGB	3 PLGB	4 LMTS	5 ACMR
Self-contained role	6	6	4	4	2
Hunter-killer role	10	8	8	10	11
TOTAL	16	14	12	14	13

The numbers in the first row indicate the number of sorties estimated to be required per designator aircrew for practice of the self-contained mission. The second row indicates the number of sorties estimated to be required for practice of the hunter-killer mission by the designator aircrews.

The number of sorties required for the bomber aircrews are not tabulated above. This approach is based on the assumption that the critical element in effective employment of laser guided munitions is the skill of the designator aircrew. The bomber sorties are necessary to maintain the competence of the aircrews assigned the task of laser designators and are also beneficial to the combat readiness level of the bomber aircrews. The bomber sorties required for the accomplishment of designator aircrew continuation training with each system are presented in Chapter VI as a system spillover.

An Example of Sub-Criteria Evaluation

All five alternative training systems discussed above were subjectively determined by the interviewed aircrew members to be capable of meeting the actual system criterion of maintaining a reasonable level of aircrew combat readiness. The number of designator sorties required to maintain this level of combat readiness varied between each alternative training system. A second actual main criterion developed in Chapter IV was that the training system should be acceptable for use worldwide in tactical air force units. This second criterion was further sub-divided into ten sub-criteria. This section will evaluate each alternative method of training with respect to each of the ten sub-criteria. The purpose of this evaluation is to demonstrate how such an evaluation

of alternatives could be conducted. The statements in this section are based upon the aircrew member interviews and subjective opinions by the writer.

Universality

The BVT system fits the sub-criterion of universality very well. Training, using this method, may be accomplished on any weapons range with no additional restrictions. The video tape recorder and playback device will be provided each fighter unit which maintains the Pave Spike capability. The BDU-33 practice bombs are currently in supply channels for all tactical fighter units.

The LGB system should be useable at any weapons range which has been cleared for laser operations. For deployed units there may be logistical restrictions due to the need to transport the heavy, bulky, inert bombs. The release of laser munitions may also be restricted due to political factors on foreign weapons ranges.

The PLGB system is somewhat limited in its universality for reasons similar to those of the LGB system. First, there must be a laser cleared range within reasonable flying distance. Second, the logistics supply requirements for tasked units will be increased due to procurement of the new piece of equipment. Supply channels will have to be established and maintained for the practice laser guidance kit as well as all the associated technical orders. Third, the expenditure of the PLGB's and the firing of lasers may not be politically acceptable on the overseas weapons ranges.

The LMFS system will likely be very desirable on weapons ranges in the United States where the equipment may be set up and maintained by

Air Force personnel. On overseas weapons ranges, it may be necessary to supplement the foreign national range personnel with American system support teams which may introduce political factors. For the use of deployed fighter units, the LMTS elements would require special consideration for transportation in that they would have to be transported to the weapons range that would be selected for laser operations. Surface vehicles may be required to provide the additional transportation. Use of the LMTS system could be restricted if there were no facilities on remote weapons ranges to support the personnel on the system support teams.

The ACMR system has one major disadvantage with regard to the subcriterion of universality. It is the probability that there will be only a limited number of the ranges available for training. This number may be limited as a consequence of the relatively large investment required in equipment, real estate, and trained personnel. Training for employment of laser guided munitions may have to compete with all the other users of the ACMR system. A small number of ACMR areas may also create problems of scheduling in order to prevent overtasking of the support bases that the TDY units would need to operate from.

Combat Fidelity

The BVT system will possibly lose some effectiveness of training if used on tactical weapons ranges. This would primarily be because few tactical weapons ranges have bomb impact scoring capability. Aircrews presently "airscore" most bomb impacts on tactical weapons ranges. Since the measure of aircrew effectiveness for the bomber aircrews will likely be the CEA of their bombs, development of an accurate scoring

system should be required for tactical range operations. If the BVT method of training were used to practice strike force tactics, it is likely that few meaningful data would be gathered for measuring CEA's. This is because strike force tactics tend to saturate the manual bomb scoring systems which the BVT system depends upon for scores. There should be no difficulty of operation of the BVT system on EW ranges. To practice combat weight maneuvering, it would be necessary to add additional stores. The simplest store to add may be the 600 gallon centerline fuel tank which adds about 4000 pounds to the takeoff weight of the aircraft.

The LGB system could be used very realistically against targets on a tactical weapons range. The number of direct hits due to the high accuracy of the laser guidance unit may produce a requirement to repair or replace the practice targets (such as the old trucks or aircraft on the range) more often than with other training systems which would probably require more range personnel. All LGB's that guide should impact within the field of view of the video tape recorder, thus providing adequate documentation of the competence of both the bomber aircrew and the designator aircrew. As the inert laser guided bomb looks like the actual weapon and leaves the aircraft with the same feel as the actual weapon, it should be very effective in providing realistic strike force practice. Carriage and employment of the inert laser guided bombs should not restrict operation on EW ranges. If the inert bomb were of the 2000 or the 3000 pound class, aircraft maneuvering weight would be close to combat maneuvering weight.

The PLGB system could be used very effectively on tactical weapons ranges. The PLGB discussed earlier is relatively small (it weighs about

thirty pounds) and if it is feasible for use it is not likely to destroy the practice targets as quickly as the inert laser guided bombs. Additionally, there is a spotting charge in the bomb which provides a cloud of white smoke at bomb impact to assist visual scoring. Neither combat strike force practice or EW range operation should be hindered by use of the PLGB system. To accomplish practice of combat weight maneuvering, an additional heavy weight store, such as the 600 gallon fuel tank, would have to be carried.

The LMTS system would enhance combat fidelity on a tactical weapons range if there were several different targets monitored by individual LMTS devices simultaneously. This would benefit practice of the hunter-killer mission where one designator may illuminate for several bombers on several different targets (which are close, but distinct) where the bombs directed at each target may impact only seconds apart. The bomber aircraft may be flown in any configuration as there is no requirement to carry any weapons when training with the LMTS system.

The ACMR system should increase combat fidelity if it is positioned over a tactical weapons range. The large area (a circle up to twenty-five miles in diameter) and the fact that no bombs need to be dropped or lasers fired should present an excellent opportunity to simulate attacks on an extremely large number of realistic targets. Practice of combat strike force tactics should be very realistic on a range of this size. The data transmitter pod, which will be mounted on each aircraft, should not restrict practice of any tactic or technique which may be used in combat.

<u>Reliability</u>

Use of the BVT system does not provide very conclusive evidence of

the skill level of the bomber aircrew. It is possible to drop bombs out of the basket (e.g., at an altitude too low for an actual LGB to guide) and still have a miss distance of less than 750 feet. The individual bomber aircrew must be aware of some parameters, such as the actual release altitude, so that he can determine if the bomb he dropped was in the basket. The BDU-33 practice bomb uses basically the same weapons release circuits as the actual weapon and frequent exercise of these circuits should help to maintain the release system reliability.

The LGB system should have a very high reproduction of the reliability of the actual weapons. Measurement of the proficiency of the aircrew is dependent upon the reliability of the laser guidance kits. Since each aircrew will probably drop only a few weapons, it is important that the reliability of these kits be monitored throughout the training program. The LGB approach to training should be the most desirable in respect to system reliability, as every component of the actual weapon system is exercised each time an inert laser guided bomb is dropped.

The reliability of the PLGB system would depend in the most part upon how much the laser seeker and guidance units are allowed to cost. The actual kits manufactured by Texas Instruments are about $3000 per unit at the plant (Ref 40:29). The prototype mentioned earlier was built with less than $150 worth of parts. No estimate was given by the builder of the prototype on the other direct and indirect costs that would be associated with production of the kits (Ref 6:40). The reliability of the PLGB is most likely correlated with the cost in that a practice kit with the reliability equal to the actual kit will likely cost much more than $150. At any cost, for the PLGB to be an effective

training device, its guidance reliability should be close to that of the actual weapon. A development program would have to be established for development, testing, and evaluation of the PLGB to determine if it can be produced with a reliability high enough to make it desirable.

The LMTS devices can be checked and calibrated for the proper light response by the support teams when they are set up. The devices are rugged and can be left in the field indefinitely with the only maintenance being the installation of batteries (Ref 13).

The ACMR system has a capability of continuous monitoring of range equipment along with real time equipment status displays. Additionally, all ranging equipment is automatically calibrated during all operations (Ref 10:9-2). Use of this system would not exercise the laser designator systems in the function of firing the lasers.

Timeliness of Data

The BVT system provides adequate bomb impact data if there is only one bomb dropped at a time and if it is dropped on a conventional weapons range. The plotting of the impact point requires visual sighting of the smoke spotting charge by the range personnel manning the spotting telescopes. Bomb impact points are estimated by various means, all subjective, on tactical weapons ranges. If the bomb impacts close to the target, then the impact could be scored on the video tape.

If the LGB impacts within the field of view of the Pave Spike television camera, the designator WSO will be able to call an estimated impact point, which can be verified by post flight video tape playback. Often, inert bombs do not mark well as the only way of determining the impact point visually is by sighting the dirt or sand thrown up in the

air. If only one inert laser guided bomb is dropped per sortie, then the post flight video tape review should be adequate for training purposes.

The PLGB system should be more desirable than the LGB system on spotting the impact point. This is due to the spotting smoke charge which helps to pinpoint the impact point for the video tape playback and the scoring personnel.

The LMTS system provides real time data on target illumination to the designator aircrew. If the laser beam is on the target, then the designator rear seat aircrew member will be viewing flashing lights through his television viewer. The bomber aircrew should have no doubt as to the location and illumination of his target when he simulates bomb release as he will also see the flashing lights. However, whether the bomber was in the basket or not will be dependent upon the personal assessment by the bomber aircrew of his position when he simulated weapons release.

The ACMR system will permit as many "hot" passes as the aircrew desires since the predicted impact requires no bombs to be dropped. The ACMR will have the capability to provide real time predicted scores if the coordinates of the target are provided to the system before attack. At the post flight debriefing, the aircrews will be able to review the mission performance in such detail that all relevant aircraft and bombing performance can be reviewed at will (Ref 10:9-4). It should be noted that this is the only training system that has the capability of providing positive data at the post flight debriefing for the actual parameters of both the designator and the bomber aircraft. The other four systems rely on recollections and inflight notes of the aircrews

in order to establish aircraft conditions at bomb release.

Flexibility

The BVT system is relatively flexible when used for aircrew training. Carriage of the practice bomb dispenser restricts very few training options. If the Pave Spike designator is inoperative, the bomber aircrew is still able to achieve a normal, ballistic bombing training mission. The BDU-33 practice bomb may be used in practice of several other weapons delivery events which may be accomplished on either a conventional range or a tactical range.

The LGB system is relatively inflexible for other training events should the laser designator be inoperative or the weapons range be closed. Once an inert laser guided bomb is loaded on an aircraft, it is very unlikely that any other effective mission could be accomplished. This is due to the aerodynamic drag, the weight of the bomb, and the cost of the laser guidance kit on the inert bomb.

The PLGB system may be utilized on any target as long as the weapons range is cleared for laser operations. If the laser were inoperative, then the PLGB would not normally be expended. A few more alternative training events could be attempted with the PLGB on the aircraft than could be with the carriage of the inert laser guided bomb.

The LMTS system is extremely flexible with respect to suitability of the aircraft for alternative training missions. If the LMTS devices were discovered to be not operational after the aircraft were airborne, an alternate weapons delivery sortie could be attempted.

The location of an ACMR determines the level of flexibility associated with it. If the ACMR is over or near a weapons range, then

the aircraft may be able to plan alternate training missions utilizing that weapons range. If there are no weapons ranges available, the aircraft should still be able to use the ACMR airspace for air-to-air training missions. Since no weapons need be carried on an ACMR mission, there should be no flight safety restrictions on where the aircraft may be operated if the ACMR is not available.

Switchology

In use of the BVT system the selection and positioning of weapons release switches is very close to the switchology used in combat. The only significant difference is that the laser illuminator will not be fired by the designator aircrew.

The LGB system should be the most desirable for the switchology sub-criterion as the switchology required for exercise of this system is exactly that of the employment of the actual weapons.

The switchology of the PLGB system is very similar to that of the LGB system. All switches are utilized as they would be in actual laser guided munitions employment.

The LMTS system does not require any switches to be positioned by the bomber aircrews. This will allow aircrews to get by with less than what is necessary to employ actual weapons and may, indirectly, contribute to switchology induced errors on employment of the actual weapon.

The ACMR system should provide close switchology reproduction to actual weapons employment. The aircraft mounted data transmitter pod requires that weapons release firing signals be initiated by the bomber aircrew (Ref 10:7-7). To accomplish this, the bomber aircrew must ac-

complish the switchology procedures required to release the actual weapon. The laser is not fired when using the ACMR training system.

Flying Safety

The BVT system fits the flying safety sub-criterion very well. There are presently few safety limitations upon carriage of the BDU-33 practice bomb or its dispenser on other training flights. The only training restricted due to carriage of this dispenser is the air-to-air combat maneuvering training. Since the laser does not have to be fired to accomplish the training either in the self-contained role or the hunter-killer role, the weapons range does not have to be cleared for laser operation.

The LGB system may be restricted for flying safety reasons. This is because the restrictions that would likely be imposed on off range carriage of the inert laser guided bomb would preclude alternative training missions. The LGB system would require use of a laser cleared weapons range.

The PLGB system would also require a laser cleared weapons range. It is possible that fewer flying safety restrictions would be put on the PLGB, due to its similarity to the BDU-33 practice bomb.

The LMTS system requires a laser cleared weapons range as the laser must be fired to cause the lights to flash. Since no bombs will be dropped, there may be a tendency for the bomber aircrews to delay their dive recovery in order to observe the target longer. When dive recoveries are delayed for any reason, the number of dangerous passes and "over G" incidents often increase as a result of the aircrews attempting to compensate for the late recovery. This is a safety of flight

factor.

The ACMR system should enhance operational flight safety. A safety feature of the ACMR is that the system alerts the ground instructor pilot at the display console in the DDS when predefined hazardous situations are develping (Ref 9:4). These hazardous situations could be "over G" flight or predicted dangerous terrain clearance. These warnings, as well as the actual "G" load put on the aircraft, are repeated at the post flight debriefing. This documentation should help the maintenance sections insure that the proper inspections are accomplished for the aircraft which had been subjected to the high "G" flight.

Availability

Use of the BVT system should not affect the turnaround time of the aircraft. The practice bomb dispenser can be quickly reloaded, and it does not have to be removed in order to accomplish normal maintenance. The BDU-33 practice bombs are rugged and can be easily downloaded for maintenance reasons if necessary.

Use of the LGB system could reduce the availability of the aircraft due to the time required for preload safety checks and uploading the inert weapons. However, a beneficial spillover of use of the LGB system is the training that it provides the munition load crews. The load crews are provided the opportunity to load and perform preflight checks of the actual guidance kits amid the normal activity of flight line operations.

Since the PLGB would be unique in that it could be used only for one training event, it could adversely affect the aircraft turnaround time. Bombs which are in the dispenser may have to be downloaded for maintenance and the extra handling may affect the reliability of the delicate laser

guidance and seeker unit.

Use of the LMTS system should not affect the availability of the aircraft. The devices are completely passive and require no inputs from any aircraft, other than laser energy. The devices can be left in position, monitoring continuously with little down time (Ref 13).

Operation of the ACMR system will affect aircraft availability and turnaround time in one significant way. This is in the availability of the aircraft mounted AIS data transmitter pods. These pods are designed to the dimensions of the Sidewinder air-to-air missile and should be easily uploaded and downloaded by munitions load crews (Ref 10:7-7). Availability of the aircraft using the ACMR system may be increased by procurement of a number of AIS pods such that their availability is not a critical factor.

System Life Factor

The sub-criterion of the system life factor should not be critical to the BVT training system. The practice bomb dispenser will be used on all missions, but this may enhance turnaround time where the bomber aircraft can be tasked for other weapons delivery missions which require the same dispenser and practice bombs. From Table I it may be determined that this alternative system requires the most sorties for the designator aircrews. The aging rate may be increased by the extra operating time of the Pave Spike systems required to support these extra sorties. This factor would lower the desirability of the alternative.

Use of the LGB system should not affect the system life factor of any aircraft equipment. It may improve reliability of the bomb ejector racks which normally are only checked periodically by munitions mainte-

nance personnel. Use of the ejector racks should provide a means of measuring their reliability, which could be a spillover of the LGB system. Aging of the Pave Spike designator system should be at a lower rate than with the BVT method of training.

The PLGB system should not affect the system life of any equipment as it requires the lowest number of designator sorties. The practice bomb dispensers will be used on each mission and thus will be aged accordingly. These dispensers are the same dispensers which are used for the regular BDU-33 practice bombs.

Use of the LMTS system should be favorable to the system life factor sub-criterion. The LMTS devices on the weapons range, however, may be aged by frequent moving from target to target.

The ACMR system should affect the system life factor of the Pave Spike system. Performance of the AIS data transmitter pods may be downgraded by constant use, but some method of life cycle testing would have to be accomplished to determine if this were the case. The ACMR system will very likely be utilized for other types of training missions when it is not being used for laser guided weapons training.

Temporary Duty

Use of the BVT system will require little TDY. Since all tactical fighter units will be able to accomplish their laser continuation training on their local weapons ranges, there will be no additional TDY required.

The LGB and the PLGB systems should be unaffected by the TDY subcriterion. The only units that may require TDY for the use of these systems will be those that do not have access to a laser cleared weapons

range.

The LMTS system should require little TDY as the cost of each individual LMTS system should be such that each local weapons range would be able to procure and maintain at least three individual LMTS systems.

The ACMR will be likely to require frequent TDY. The amount of real estate required for an ACMR may preclude each unit from having an ACMR located nearby, especially the overseas units. Although this training system would require TDY, it may be possible to accomplish other training in conjunction with the laser guided weapons training. Aircrews normally can be expected to accomplish one effective training sortie per day of TDY. At this rate, thirteen missions on an ACMR would require almost three weeks of flying per aircrew. This would indicate that about three weeks of TDY per six month training period would be required for each aircrew. Additionally, one instructor pilot may be required from each unit to be on TDY to the ACMR site in order to perform as the range safety officer.

Ranking of Alternatives

An example of how the alternative training systems might be evaluated and ranked is shown in Table II on the next page. The alternatives are evaluated within each suggested sub-criteria class developed in Chapter III. The ratings used in the example reflect subjective evaluations by the writer.

The alternative training systems are evaluated with respect to each sub-criterion with a series of special symbols. The "++" symbol indicates a "most desirable" evaluation, and the "--" symbol indicates a "least desirable" rating. If a particular system is indifferent with

respect to a sub-criterion, then a symbol of "0" may be used. If it is clear that there are distinct levels of desirability with respect to a certain sub-criterion, then the ratings could be indicated in order from the most to the least desirable as follows: "++, +, 0, -, --." An example of this would be the sub-criterion of universality in Table II. If there is no discernable difference between several alternatives, then they all may have the same symbol.

Table II. Example of Sub-Criteria/Alternative Training Systems Array.

SUB-CRITERIA	ALTERNATIVE 1 BVT	2 LGB	3 PLGB	4 LMTS	5 ACMR
Universality	++	-	+	0	--
Combat Fidelity					
1. TTA	--	+	++	+	+
2. CSFP	--	-	0	+	++
3. CWM	0	++	0	+	+
Reliability	0	0	--	+	++
Timeliness	0	0	+	+	++
Flexibility	+	--	-	0	+
Switchology	+	++	+	--	+
Flying Safety	+	--	-	0	++
Availability	0	-	-	+	+
System Life	-	0	+	-	0
Temporary Duty	++	0	0	+	--

An advantage of an array similar to Table II is that it presents, on a single page, a pictorial evaluation of all the relevant factors, or sub-criteria, which influence the desirability of a system. For example; if the decision maker accepted the subjective assignment of the symbols as pictured in Table II, then he might consider the ACMR system to be very desirable. But, he would have to judge if the ACMR system would pass the "universality" sub-criterion. If not, then it may not be acceptable for use for laser guided aircrew training.

Summary

Five alternative laser guided weapons training systems were subjectively determined to be capable of maintaining a reasonable level of combat readiness. The critical element in the effective employment of laser guided weapons was subjectively determined to be the skill of the designator aircrew. For this reason, bomber aircrew continuation training was considered to be supportive to the designator aircrew continuation training. The five alternative systems were identified as the basket and video tape (BVT) system, the laser guided bomb (LGB) system, the practice laser guided bomb (PLGB) system, the laser monitoring/target scoring (LMTS) system, and the aerial combat maneuvering range (ACMR) system. Suggested designator aircrew continuation sortie requirements were presented for each alternative system. Each alternative system was subjectively evaluated with respect to each of the sub-criteria developed in Chapter III for illustrative purposes.

The next chapter contains a discussion of the costing approach used in cost effectiveness analysis and presents the cost elements and examples of the estimated costs for implementation of each of the five alternative training systems presented in this chapter.

Chapter VI

COSTS AND RELEVANT FACTORS

Introduction

Each alternative presented in Chapter V has economic costs associated with its selection. Economic costs are those costs that represent benefits lost to the decision maker and are often referred to as "alternative costs" or "opportunity costs" (Ref 7:25). These terms are meant to indicate that the resources which are committed as a consequence of choosing a particular alternative are not available for use in any other opportunity. Had that particular alternative not been selected, then the resources could have been put to other uses.

In this study resources are measured, where possible, in monetary units. This is a convenience for analysis, as the use of dollars permits the aggregation for comparison of many different types of resources (Ref 25:5).

Each of the five alternative training systems identified in Chapter V will be evaluated in this chapter with respect to its economic costs. The dollar costs that are presented as "estimated" costs in this chapter were obtained from sources referenced in the bibliography. These estimates were obtained with the understanding that they would be presented as "ball park" estimates and were to be used only for the purposes of illustrating roughly the magnitude of the costs. The costs

that are presented as "assumed" costs in this chapter are meant to be examples of actual estimated costs. This procedure should not affect the validity of the methodology proposed in this study. The emphasis on design of the cost estimate structure is directed toward identification of all the relevant elements of each system's cost and a cost structure that is mutually exclusive.

Cost Elements

There are three component elements of any alternative solution to a problem; viz., (1) the component that is common to all alternatives, (2) the component of specified differences, and (3) the component of the remaining unspecified differences (Ref 7:47). Economic costs of alternatives may also be divided into three similar component elements. Most of the costs of tactical aircrew training are common to all of the alternatives; for example: the pay and allowances of the aircrews and maintenance personnel currently assigned, present aircraft operations and maintenance costs, basic hardware costs, and the costs of the existing bases and support facilities. Since these costs are assumed to be equal and to apply to all alternatives, their measure makes no difference to the selection of the best alternative.

Costs that are not common to all alternatives may be specified or unspecified. Examples of specified costs are the costs of the development and procurement of the practice laser guided bomb and the recurring operation costs of the ACMR. The unspecified costs are those costs which are generally more difficult to measure in units common to all alternatives. Examples of unspecified costs are: the effect on morale and personnel retention as a result of frequent TDY; potential aircraft

accident rates inherent in operation of a particular alternative training system; and the costs (or benefits) of spillover effects of each alternative.

Relevant Costs

The only costs that should be estimated in a cost effectiveness analysis are the relevant costs. Relevant costs may be thought of as the costs of the future. Any cost of the past is considered as a "sunk" cost and thus, is irrelevant with respect to decisions of the future. Current or future decisions should not be affected by sunk costs (Ref 7: 33).

All the incremental cost increases or decreases with respect to the common cost that will be experienced as a consequence of choosing a particular alternative training system are relevant costs (Ref 25:10). When the sum of these estimated costs is computed, it is referred to as the incremental cost of that alternative with respect to the other alternatives under consideration.

Each of the component cost elements of the alternative costs may be placed in one of three categories to enable a cost analyst to be comprehensive in the estimation of total costs. The first category is that of dollar expenditures, or costs that can be evaluated in dollars (Ref 7:41). This category normally contains the most obvious costs-- those which have to be identified and funded for a particular system.

The second category is that of other costs that can be quantified (Ref 7:41). An example of this category of costs is the estimated numbers of man days of TDY which will be required for a particular alternative. The per diem cost in dollars may be estimated easily, although

the opportunity cost of other possible uses of the personnel may be difficult to translate into dollars.

The third category is that of all the costs which can not be quantified (Ref 7:41). The costs associated with a change in the aircraft accident rate due to selection of a particular alternative would likely fit into this category. Likewise, the reduction of effectiveness due to poor morale of critical personnel when required to go on frequent TDY can not be effectively quantified. Evaluation of this last category may best be accomplished by subjective assessments on the part of the decision maker.

It is important to note that the cost estimates in this chapter are examples of planning estimates; not funding estimates. Planning estimates often omit whole areas of costs -- those major or minor areas which are identical for all the alternatives. Funding estimates are cash flow estimates -- they measure the number of dollars that will be required to implement a particular system (Ref 19:26-28). Because of this difference, the costs presented here should not be taken as the total cost of any one alternative training system. The primary purpose of these planning cost estimates is not to accurately forecast costs for budget administration; but to provide estimates of the relative costs of the competing systems (Ref 22:I-2).

Excluded Costs

The earlier discussion of the cost component elements and relevant costs indicated that the common costs should be excluded from a cost effectiveness analysis. The major costs which fit into this category and are specifically excluded from this study are as follows:

1. Pay and allowances. All pay and allowances of required personnel are excluded from this analysis with the exception of the differential pay and allowances that are caused as a result of selecting a particular alternative system.

2. Logistics, operations, and maintenance costs. All normal operating costs are excluded with the exception of those costs which may be charged to procurement and use of an individual alternative system and are unique to that system.

Discount Factor

A decision to procure any military hardware carries with it an obligation to purchase the related system for that hardware. The related system includes the facilities, the acquisition and training of personnel, support and test equipment, and a host of other related items. There is also the implicit obligation to incur the expense of the recurring support and training costs as long as the system remains in the active inventory (Ref 22:I-1). These costs in the near future must be considered in order to reduce the probability of unforeseen cost consequences.

In order for the stream of future costs of an alternative training system to be truly comparable with the other alternatives, it is necessary that the cost streams be normalized, or discounted, through time. If everything else is equal in an analysis, a future cost is preferred over a current one (Ref 25:8). This implies that future dollars are worth less than current dollars. In order to add together dollars spent in different periods, it is necessary to discount the future dollars (Ref 7:51). The procedure for discounting is to first select

a discount rate and then apply that rate to determine the present value of a future cost. For example, if the discount rate were ten per cent per year, a dollar to be spent one year from now is estimated to be worth only ninety cents today. A dollar to be spent two years from now is worth only eighty-one cents today.

The proper discount rate to use is a subject of much discussion and many opinions in the literature (Ref 16:227-8). The range of suggested discount rates for military purposes vary from about five per cent to about fifteen per cent. As a comparison of the effects of this range, a dollar seven years in the future is worth seventy-one cents today discounted at five per cent and only thirty-seven cents discounted at fifteen per cent.

It may be that the selection of the precise discount rate is not as important as explicitly stating the discount assumptions and then testing for the consequences of alternative assumptions (Ref 16:230). By varying the discount rate, it is possible to determine if the ranking of alternatives is sensitive to the discount rate. If it is, then more time should be given to determining the appropriate rate to be used. The sensitivity of the discount rate will be explored at four discount rates in this study: zero, five, ten, and fifteen per cent.

Basic Cost Assumptions

Composition of the Tactical Air Forces

During the seven years of future operations within the scope of this study, each of the major tactical fighter commands is assumed to possess seven wings of tactical fighter aircraft for a world-wide Air

Force total of twenty-one wings. Each of the two overseas commands--PACAF and USAFE--are assumed to be tasked with maintaining two wings at combat readiness for the employment of laser guided munitions. In TAC, three out of the seven TAC fighter wings are assumed to be tasked with the same combat readiness requirement. This total of seven laser guided munitions tasked wings are further assumed to be F-4 aircraft equipped with the Pave Spike laser designator system. The above assumptions are in line with the assumption in Chapter I that there will be unit mission specialization in the future within the tactical fighter forces.

Each laser capable F-4 wing is assumed to possess seventy-two fighter aircraft and is further sub-divided into three flying squadrons for command and control purposes. Each wing is assumed to be manned by eighty combat ready two-man aircrews including commanders and operations staff officers. It is assumed that normal attrition due to change of assignment and separation from the service is balanced by acquisition of replacement, combat ready aircrews.

Since each of the wings will be tasked with several types of complex weapons other than laser guided munitions, it is likely that only a portion of the aircrews in any wing will be required to maintain combat readiness in laser illumination. To this end, it is assumed that thirty aircrews per wing will maintain combat ready status as laser designators, while the other fifty aircrews will be utilized as the bombers in the laser hunter-killer role. It is assumed that the other fifty aircrews will specialize in employment of other sophisticated air-to-ground weapons systems.

Periodic Alternative Training Requirements

The preceding force composition assumptions coupled with the sortie requirements presented in Table I form the bases for the data arrayed on the next page in Table III. The data in this table are calculated for a normal six month training period and reflect the estimated sortie requirements for the thirty designator aircrews in each hypothetical laser tasked fighter wing. Each estimated requirement is sub-divided into the self-contained role and the hunter-killer role for clarity. For example, with the BVT system each of the thirty designator aircrews is estimated to require six self-contained and ten hunter-killer sorties per six months. This would result in a total of 180 self-contained and 300 hunter-killer sorties respectfully for the six month training period.

There are three mission profiles considered. The profiles are identified as profile one, two, and three for the purpose of this study. Profile one is a flight of two designator aircraft planned to practice the self-contained role. Only two aircraft are suggested so as to provide sufficient time for each designator aircrew to practice the necessary techniques for self-contained delivery. Profile two is a flight of four aircraft consisting of two designator aircraft and two bomber aircraft. Profile two will be planned to practice the hunter-killer tactics used when there are two designators available for two bombers. Profile three is a flight of three bomber aircraft with only one designator aircraft. This flight will also be planned to practice hunter-killer tactics. It is assumed for planning purposes that half of each alternative total hunter-killer requirement will be flown on profile two missions and half will be flown on profile three missions. To illustrate--of the 240 hunter-killer sorties of the LGB system, 120

Table III. Estimated Designator Requirements per Wing per Six Month Training Period.

ALTERNATIVES		Sorties		Missions/sorties			Range Periods	Bombs	Total Range Periods	Total Bomber Sorties	Total Designator Sorties
		per Aircrew	per Wing	Profile							
				1	2	3					
BVT	Self-contained	6	180	90/180	0	0	90	720	315	600	480
	Hunter-killer	10	300	0	75/150	150/150	225	1950			
LGB	Self-contained	6	180	90/180	0	0	90	76	270	480	420
	Hunter-killer	8	240	0	60/120	120/120	180	126			
PLGB	Self-contained	4	120	60/120	0	0	60	150	240	480	360
	Hunter-killer	8	240	0	60/120	120/120	180	600			
LMTS	Self-contained	4	120	60/120	0	0	60	0	285	600	420
	Hunter-killer	10	300	0	75/150	150/150	225	0			
ACMR	Self-contained	2	60	30/60	0	0	30	0	278	661	390
	Hunter-killer	11	330	0	83/166	165/165	248	0			

sorties will be flown on sixty profile two missions while 120 sorties will be flown on 120 profile three missions.

The "range period" column reflects the number of thirty minute range periods required for each alternative, assuming that all missions are effective. For example: it is estimated that use of the LMTS system would require, for one wing, a total of sixty profile one (self-contained) missions. Since only one training mission would normally be allowed on the weapons range during one thirty minute period, this would be equivalent to sixty range periods. Practice of the hunter-killer role is estimated to require seventy-five profile two missions and 150 profile three missions for a total of 225 missions. This is equivalent to 225 range periods which is reflected in the "total range periods" column. It will probably require a higher number of range periods to be scheduled to compensate for missions lost due to adverse weather, aircraft malfunctions, etc.

The "bombs" column reflects the estimated number of bombs required if the suggestions stated in Chapter V are accepted for each alternative training system. The BVT system bomb requirements are calculated by assuming four bombs per bomber on each profile one and two sortie and three bombs per bomber on each profile three sortie. It is assumed for the purpose of cost estimating in this study that roughly twenty per cent of both the LGB's and the PLGB's will not be effective when dropped for training purposes. The LGB system requirements reflect two effective inert laser guided bombs per aircrew assuming that roughly twenty per cent are not effective. The figure of twenty per cent is assumed only for the purpose of this study and is not meant to imply that the actual reliability of the laser guided weapons is eighty per

cent. This assumed ineffective rate will increase the number of bombs to the expected number reflected in the table. The PLGB system has the same twenty per cent factor applied to its requirement of one PLGB per sortie to obtain the expected number of PLGB's which will be required.

The "total bomber sorties" column reflects the total number of bomber sorties which will be needed to support the estimated requirements for practice of the hunter-killer role. No bombers will be used for practice of the self-contained role on the profile one missions. Two bomber sorties will be required for each profile two mission and three bomber sorties will be required for each profile three mission. For example; the PLGB system is estimated to require sixty profile two missions (120 bomber sorties) and 120 profile three missions (360 bomber sorties) for a total of 480 bomber sorties per wing per six months.

The "total designator sorties" column is simply the sum of the two entries for each alternative in the "sorties per wing" column. For example; the BVT system is estimated to require 180 self-contained designator sorties and 300 hunter-killer designator sorties for a total of 480 designator sorties per wing per six months.

Evaluation of the Common Cost Elements

There are several cost elements which may be common to several or all of the alternative systems evaluated in this study. These cost elements include the operations costs of the Pave Spike designator system, the costs of the aircraft which are required to be used for aircrew training, the costs of TDY required for aircrew training, and the costs of the weapons ranges required for the air-to-ground role of tactical weapons delivery. Discussion of the pertinence of each of these

cost elements and illustrative calculations of estimates of each of these cost elements are presented in Appendix E of this study.

The discussion and calculations provide for the measure of each of the four cost elements mentioned above as follows. The operations costs of the Pave Spike designator systems are measured in dollars. The costs of the aircraft used for the aircrew training are separated into two basic opportunity cost categories--operational training flying time and operational support flying time. The TDY costs are estimated in dollars and also, in man days of TDY required. The weapons range costs are represented as opportunity costs of the numbers of hours of range operation required for each alternative system assuming thirty minutes per required range period.

Determination of the System Costs

There are two basic categories of cost over the life of a training system. The first is the one-time or non-recurring cost such as the development of required hardware and the initial investment required. The second is those costs that recur and that are proportional to the length of operational life and the intensity of operations (Ref 25:7).

Cost data for each alternative system will be divided and placed in one of the following categories: research and development, initial investment, or annual operations. These three categories, or phases, are the categories used by practitioners of the cost estimating and cost effectiveness professions. This basic trinary structure will include all relevant costs and will aid in assuring comprehensive coverage and time phasing of all alternatives (Ref 25:6).

The category of research and development costs will be only for

systems or training weapons which will have to be developed for future use. When applicable, this category will include all costs of system design and management; sub-system development and testing; and system integration, testing, and evaluation (Ref 19:67). The alternative training systems in this study which are likely to have costs in this category are the PLGB, the LMTS, and the ACMR systems.

The initial investment category will be applicable to those systems which will have to be developed and introduced into the force and the logistics system. The costs which will be included in this category are facilities improvement, mission equipment and aerospace ground equipment investment, initial spares and stocks, and initial training and travel for personnel (Ref 19:67). Again, the PLGB, the LMTS, and the ACMR systems are likely to have costs in this category.

The last category, annual operations costs, will apply to all systems and is an important cost factor in any tactical weapons system alternative. Costs which are included in this category are facilities maintenance; equipment replacement and maintenance; communications and similar equipment rental; annual pay, allowances, and training costs for required personnel; transportation and other logistics costs; and cost of training replacements due to discharge and PCS (Ref 28:III-24).

Alternative System One

The basket and video tape system is the first alternative training system to be evaluated for its estimated economic costs. The BDU-33 practice bomb has been in the inventory for some time and there will be no research, development, or initial investment costs incurred if this system is selected.

The only relevant costs of the BVT system are the recurring operations costs. These include the procurement and logistics cost of the additional BDU-33 practice bombs; the cost of the extra sorties for the designator aircraft; the cost of the extra Pave Spike operations; the number of bomber sorties required for hunter-killer training; and the number of weapons range periods.

The data in Table III indicate that a total of 2670 BDU-33 practice bombs are estimated to be required per six months for one wing. The seven laser tasked wings may thus be estimated to require fourteen times 2670 or 37,380 practice bombs per year. The unit cost of these bombs is assumed to be $24.00 and the average total logistics costs per bomb is assumed to be $1.50.

Cost data calculated from these estimates and assumptions are presented in Table IV on the next page.

Alternative System Two

The second alternative training system, that of training with inert laser guided bombs, is similar to the BVT system in that no research, development, or initial investment costs will be incurred. The inert bombs and the laser guidance kits are now, or will be, at the local weapons storage facility for each laser tasked wing. It will be necessary to replenish the stock of items that will be expended and the cost of doing this falls into the recurring operations cost category.

The cost of the laser seeker and guidance kits is assumed to be $3000 per kit throughout the time period of this study. Based on the estimated requirements presented in Table III of a total of 202 inert bombs per wing per six months, the total number of inert laser guided

Table IV. Basket and Video Tape System Incremental Costs.

Research & Development Costs	(not applicable)
Initial Investment Costs	(not applicable)
Annual Operating Costs	
Practice bombs:	
Procurement of bombs (37,380 bombs at $24.00)	$ 897,120
Logistics support (37,380 bombs at $1.50)	56,070
Range hours (7 wings at 630 half-hour periods)	(2205 hours)
Operational training sorties:	
Bomber sorties (7 wings at 1200 sorties)	(8400 sorties)
Designator sorties (7 wings at 960 sorties)	(6720 sorties)
Designator extra sorties (7 wings at 240 sorties)	(1680 sorties)
Pave Spike operations extra costs (1680 sorties at $33.48)	56,246
TOTAL	$ 1,009,436

Note: The data in this table are based on data in Table III and are meant to be illustrative of the type and magnitude of costs expected to be associated with this training system. The Pave Spike operations extra cost per sortie, $33.48, is taken from Appendix E for a MTBF of 85 hours and is used for Tables IV, V, VII, and VIII.

bombs to be dropped by the seven wings per year is estimated to be 2828. It may be that some, or all, of this requirement could be supplied by kits which are "surplus" to the war reserve stocks maintained in the weapons storage facilities. If so, this should reduce the cost of this alternative method of training, as the cost of these war reserve stocks is a sunk cost and irrelevant to this analysis. In the opinion of the writer, it is more likely that these surplus kits will be used for training only if they are replaced by new kits for storage.

The actual 2000 pound bomb is stated to cost $715 (Ref 38:7-C-1). The cost of an inert 2000 pound bomb is assumed to be $350. The logistics costs of shipping, storage, inspection, and handling of the inert bombs and laser seeker and guidance kits is assumed to be $65 per bomb.

The estimated cost data for the LGB systemare presented in Table V.

Alternative System Three

Procurement and use of the alternative training system using the practice laser guided bomb will require expenditures of resources in each of the three cost categories--research and development, initial investment, and recurring operational costs. The prototype PLGB was not dropped from a tactical aircraft, to the personal knowledge of the writer, and the status of its continued development is not clear. All costs that might be incurred to enable development of the PLGB should be considered in order to determine the best estimate of the development costs. This includes the flying time for test drops. It is assumed that the development, test, and evaluation program would run for six months and would require an outlay of $35,000. This amount of money would allow a sufficient number of practice bombs to be built so

Table V. Laser Guided Bomb System Incremental Costs.

<u>Research & Development Costs</u>	(not applicable)
<u>Initial Investment Costs</u>	(not applicable)
<u>Annual Operating Costs</u>	
Inert laser guided bombs:	
Procurement of bombs (2828 bombs at $350)	$ 989,800
Procurement of laser kits (2828 kits at $3000)	8,484,000
Logistics support (2828 units at $65)	183,820
Range hours (7 wings at 540 half-hour periods)	(1890 hours)
Operational training sorties:	
Bomber sorties (7 wings at 960 sorties)	(6720 sorties)
Designator sorties (7 wings at 840 sorties)	(5880 sorties)
Designator extra sorties (7 wings at 120 sorties)	(840 sorties)
Pave Spike operations extra costs (840 sorties at $33.48)	28,123
TOTAL	$ 9,685,743

Note: The data in this table are based on data in Table III and are meant to be illustrative of the type and magnitude of costs expected to be associated with this training system.

that the reliability of the production bombs could be predicted.

The initial investment costs should include the costs of all activities that are associated with preparing the logistics system in totality to receive, support, and maintain the reliability while in storage of the practice laser guided bombs (Ref 20:3). A meaningful estimate of these costs would require extensive study of the performance specifications and physical descriptions of the bombs and kits as well as the required aerospace ground support and test equipment. This is beyond the scope of this study. The initial investment costs are assumed to be an average of $50,000 per laser tasked wing.

It is assumed that no additional personnel will be required to maintain and handle the PLGB due to its similarity to the existing practice bomb. However, two sensor specialists and two munitions loading specialists are assumed to be sent on TDY for 4 weeks each to become instructors on the maintenance and operation of the practice laser guided bombs. It is expected that these personnel will conduct on-the-job training for other wing personnel on the requirements of the practice bomb and laser guidance and seeker kit. The one time TDY requirement for the four specialists is assumed to cost $1,920 in per diem and travel pay for each laser tasked wing.

From the data in Table III, it may be estimated that each of the seven laser tasked wings will require an expected 1500 PLGB's for an expected total of 10,500 PLGB's per year. This is a significant number of units and the estimated costs should be determined as accurately as possible. One method of estimating the probable cost of a production PLGB is to look at its differences and similarities in aspect and performance relative to the full-size laser guidance kits. The most reliable method of determining the unit cost of the PLGB kit is through use

of a cost estimating relation (CER). A CER is defined as a ". . . generalized statistical distillation of multiple cost experiences covering a defined type or area of cost" (Ref 19:96). For the purpose of this study, the average unit cost of a PLGB is assumed to be $400.

The recurring logistics costs include the inspections, preservation, shipping, intermediate storage, and final transportation and storage costs. These costs are lumped into one cost element which is assumed to be an average of $2.00 per bomb.

Since the PLGB training system requires the lowest number of Pave Spike designator sorties, there will be no costs estimated for additional Pave Spike operations costs. This follows the concept of excluding the common cost components.

Cost data calculated from the assumptions and estimates above are presented in Table VI on the next page.

Alternative System Four

The laser monitoring/target scoring system will have costs in all three categories--development, initial investment, and recurring operational costs. The cost estimates for the LMTS system are based on the following reasoning.

There will be little research required for the prototype LMTS sensor unit. The technology is already in existence and operational in a sophisticated laser monitoring and data gathering system--the pulsed image converter system (PICS). The sensor devices will be similar to those in the PICS and will be adapted to fulfill the LMTS function. The sensor and light devices, the suspension paraphernalia and the power supply unit

Table VI. Practice Laser Guided Bomb System Incremental Costs.

Research & Development Costs	
Development and tests of the practice laser guided bomb	$ 35,000
TOTAL	$ 35,000
Initial Investment Costs	
Support and test equipment (7 wings at $50,000)	$ 350,000
Specialist training (7 wings at $1,920)	13,440
TOTAL	$ 363,440
Annual Operating Costs	
Practice laser guided bombs:	
Procurement of bombs (10,500 bombs at $400)	$ 4,200,000
Logistics support (10,500 bombs at $2.00)	21,000
Range hours (7 wings at 480 half-hour periods)	(1680 hours)
Operational training sorties:	
Bomber sorties (7 wings at 960 sorties)	(6720 sorties)
Designator sorties (7 wings at 720 sorties)	(5040 sorties)
TOTAL	$ 4,221,000

Note: The data in this table are based on data in Table III and are meant to be illustrative of the type and magnitude of costs expected to be associated with this training system.

will be wholly self supporting and may be placed in a small van or utility trailer for storage or transportation (Ref 13).

To provide flexibility of operation, each weapons range is assumed to be authorized three LMTS sensor units. This authorization should provide availability of at least one operational unit when required. If seven weapons ranges were used for laser guided munitions training, then a procurement of twenty-one units would provide three units per weapons range.

An estimate was provided to the writer for all outlays that will be incurred to enable development of the prototype LMTS sensor unit. The cost of development for the first unit was stated to be $5000, if it were developed within the Air Development and Test Center facility at Eglin AFB, Florida (Ref 13). If a total of twenty-one units were procured, it is assumed that the unit cost of the twenty-first production unit could be reduced to $4000. For this study, an average cost for the twenty-one units is assumed to be $4400.

A LMTS sensor unit would not require extensive test equipment and most faulty components would be relatively inexpensive and could feasibly be discarded rather than repaired. The cost of acquiring and stocking spare parts to calibrate and operate a sensor unit was assumed to be $1000 per year (Ref 13). This figure included the power and fuel supplies to keep the equipment fully charged and running and ready for use for normal operations. This amount should provide a level of preventive maintenance and modernization of equipment such that the useable life of each unit should extend through 1980 (Ref 13).

There will be one time costs of transporting the units to each weapons range. If the units were assembled at Eglin AFB, it is pos-

sible that military airlift would be tasked to transport each unit to the nearest suitable airfield. From there, it would require some other mode of transportation. Due to the unknown locations of future weapons ranges and the number of modes of transportation that could be required, these costs will not be estimated in this study.

The maintenance requirements of the LMTS sensor units are assumed to be fulfilled by military specialists. Proper analysis of the operational requirements to support the units will identify the technical skills required to maintain the sensor units. It is possible that through on-the-job training some of the presently authorized range personnel can be qualified to maintain and calibrate the sensor units. However, for the purposes of this study, it is assumed that no more than one specialist will be assigned to each weapons range to maintain the LMTS sensor units. It is assumed that he will have the rank of staff sergeant. Other personnel are assumed to be available to assist this staff sergeant when required to move and set up the sensor units.

The staff sergeant is assumed to possess the same qualifications and to require the same training as the Avionics Sensor System Technicians (Air Force speciality code 329X0A) that maintain and calibrate the laser designator systems. These technicians require twenty-one weeks of formal school before they are assigned to an operational unit (Ref 38:8-C-1). With a reasonable allowance of time for travel, leave, and inprocessing this figure is adjusted to twenty-six weeks. An overlap of twenty-six weeks is required to provide continuous personnel support. If a normal tour of duty is assumed to be three years, then this half year overlap is equivalent to 1.17 persons on a yearly basis.

The assumed yearly cost of pay and allowances for a staff sergeant

is roughly $9000. From this the personnel support cost for each range is estimated to be 1.17 times $9000, or $10,530.

Evaluation of the preceding assumptions and cost estimates yields that data presented in Table VII on the next page.

Alternative System Five

Acceptance of the air combat maneuvering range training system should incur costs in only two categories--initial investment and recurring operational costs. Since the ACMR is capable of fulfilling many aircrew training roles, only a portion of the total ACMR costs will be used for the cost comparison of alternative systems.

For the purpose of this study, a total of four ACMR individual systems are assumed to be procured--one each for PACAF and USAFE, and two for TAC. These ranges are assumed to be located such that one PACAF wing, one TAC wing, and both USAFE laser tasked wings must go on TDY to utilize an ACMR for aircrew training.

Each ACMR should be scheduled to provide 2000 hours of training time per year. The 2000 hours does not reflect the impact of down time for adverse weather (on the range or at the aircraft base of operations) and unscheduled maintenance. It is assumed that the unscheduled down time will reduce the available training time by twenty per cent, or 400 hours. Thus, the four ACMR locations are assumed to provide a total of 6400 hours of available range time per year. The data in Table III indicates that 278 thirty-minute range periods are estimated to be required per wing every six months for training with the ACMR system. The seven laser tasked wings should then require 1,946 hours of actual range time per year.

Table VII. Laser Monitoring/Target Scoring System Incremental Costs.

Research & Development Costs	
Development of prototype	$ 5,000
TOTAL	$ 5,000
Initial Investment Costs	
LMTS units (21 units at $4,400)	$ 92,400
Transportation costs (21 units)	(not evaluated)
Initial training (26 weeks at $9,000 annum for 7 ranges)	31,500
TOTAL	$ 123,900
Annual Operating Costs	
Pay and allowances (7 technicians at $10,530)	$ 73,710
Logistics and maintenance (21 LMTS units at $1,000)	21,000
Range hours (7 wings at 570 half-hour periods)	(1995 hours)
Operational training sorties:	
Bomber sorties (7 wings at 1200 sorties)	(8400 sorties)
Designator sorties (7 wings at 840 sorties)	(5880 sorties)
Designator extra sorties (7 wings at 120 sorties)	(840 sorties)
Pave Spike operations extra costs (840 sorties at $33.48)	28,123
TOTAL	$ 122,833

Note: The data in this table are based on data in Table III and are meant to be illustrative of the type and magnitude of costs expected to be associated with this training system.

The total costs of the ACMR system used for laser guided munitions training will be taken as a fixed ratio of the total ACMR dollar cost. This ratio should be equivalent to the required range time divided by the available range time. Dividing 1946 hours by 6400 hours yields a value of 0.304 for this ratio.

Procurement costs of each ACMR are estimated to vary from roughly five million dollars for the first unit to four million dollars for the fourth unit (Ref 33). The total procurement costs for four units are assumed to total eighteen million dollars. It is assumed that the ACMR will be located on land which is presently controlled or leased by the government for use as weapons ranges. If this assumption is correct, there will be no dollar outlay for cost of real estate. However, the real estate used for an ACMR complex has an inherent cost--its alternative value. If the land is government owned, it could possibly be used for some other training or research purpose. The values assigned to it for this alternative use would have to be determined with respect to that alternative use. If leased only for the use of the ACMR, then its alternative cost would be the total dollar value associated with the lease agreement. The initial, one time transportation costs of the ACMR equipment will not be considered for the same reasons as the LMTS transportation costs were not evaluated.

There will be costs associated with the functions of organizing and establishing each ACMR complex. These functions are assigning and training personnel; providing fixed facilities and amenities for effective operation; establishing the necessary supply inventory, power sources, and communications networks; and other start up costs. The costs of these functions are dependent upon the locations selected for each ACMR complex

and the facilities presently available there. For the purpose of this study, all of these costs are lumped into one cost element assumed to cost an average of $150,000 per location.

It is assumed that ten AIS pods per wing will be required to provide the necessary level of pod availability required for effective unit training on an ACMR. The average unit price for an AIS pod and its associated ground test and support equipment is estimated to be $80,000 (Ref 33).

Ten persons are estimated to be sufficient to operate and maintain one ACMR on a continuing basis (Ref 33). No assumption is made whether these persons should be military or civilian contract personnel. There could be additional cost factors involved if civilian contract personnel were required to be assigned to remote overseas locations to support an ACMR. Evaluation of the Navy ACMR presently operating at the Yuma range in Arizona may yield more definitive data about what the personnel requirements should be for the ACMR. The aggregate of the annual costs of all the recurring costs of personnel, replacement and maintenance of equipment and facilities, transporation and logistics, and similar cost elements is estimated to be $600,000 per ACMR complex. This figure includes maintenance required for the AIS pods (Ref 33).

The estimated costs of the TDY are taken from the "TDY Costs" section of Appendix E to this study. The TDY costs for the bomber aircraft and aircrews are not evaluated as it could not be reasonably determined if these aircraft would be provided by the host base unit or if the bomber aircraft would be on TDY to fulfill some other training requirement. The ACMR cost data based on the above assumptions and estimates are presented in Table VIII on the next page.

Table VIII. Air Combat Maneuvering Range System Incremental Costs.

Research & Development Costs		(none identified)
Initial Investment Costs		
ACMR basic equipment (4 locations)	$18,000,000 times 0.304 =	$ 5,472,000
AIS pods (10 pods for 7 wings at $80,000)		5,600,000
Transportation cost (4 complete units)		(not evaluated)
Start up costs (4 locations at $150,000)	$ 600,000 times 0.304 =	182,400
TOTAL		$ 11,254,400
Annual Operating Costs		
ACMR aggregate recurring costs (4 locations at $600,000)	$2,400,000 times 0.304 =	$ 729,600
TDY costs:		
Man days for pay & allowances (4 wings at 22,392 man days at $10)		895,680
Transportation cost (4 wings at 936 persons at $70)		262,080
Operational support ferry sorties (4 wings at 144 sorties)	(576 sorties)	
Range hours (7 wings at 556 half-hour periods)	(1946 hours)	
Operational training sorties:		
Bomber sorties (7 wings at 1321 sorties)	(9254 sorties)	
Designator sorties (7 wings at 780 sorties)	(5460 sorties)	
Designator extra sorties (7 wings at 60 sorties)	(420 sorties)	
Pave Spike operations extra costs (420 sorties at $33.48)		14,061
TOTAL		$ 1,901,421

Note: The data in this table are based on data in Table III and are meant to be illustrative of the type and magnitude of costs expected to be associated with this training system.

Comparison of the Alternatives

Comparison of System Opportunity Costs

The estimated yearly costs of each alternative training system which were not measured in dollars in this chapter are displayed in Table IX on the next page. The cost data in this table are opportunity costs or alternative costs. The costs reflect the estimated designator requirements presented on page ninety-eight and the force composition assumptions discussed on pages ninety-five and ninety-six.

The "weapons range hours" column contains values of the minimum number of hours of effective weapons range operation estimated to be required if each training mission utilized a thirty minute range period. The values are the aggregate requirement of all seven laser tasked wings on a yearly basis. The "ACMR range hours" column contains the number of effective ACMR range hours of operation estimated to be required if each effective ACMR training mission utilized a thirty minute range period. Again, this is the requirement for all seven laser tasked wings.

Under the "flying sorties" column only the ACMR alternative has any operational support flying costs. This figure is the minimum number of ferry flights estimated to be required for the normal TDY operations of four fighter wings. All five alternative training systems have costs calculated in the "operational training" column. The values in both the "bomber" column and the "designator" column are the estimated total number of sorties required by each system. The "extra designator sorties" column contains the number of designator aircraft sorties which are over the minimum number of designator sorties required by any alternative. In this illustrative analysis, the PLGB alternative

Table IX. Estimated Annual Opportunity Costs for the Aircrew Training Systems.

ALTERNATIVES	Weapons Range Hours	ACMR Range Hours	Operational Support	Operational Training		Extra Designator Sorties	Temporary Duty Man Days
			Ferry Sorties	Bomber	Designator		
1 BVT	2205	0	0	8400	6720	1680	0
2 LGB	1890	0	0	6720	5880	840	0
3 PLGB	1680	0	0	6720	5040	0	0
4 LMTS	1995	0	0	8400	5880	840	0
5 ACMR	0	1946	576	9254	5460	420	22,392

Note: The data in this table are meant to be illustrative of the type and magnitude of the opportunity costs expected to be associated with each alternative training system.

requires the minimum number of designator sorties. Thus, the PLGB alternative requires no extra designator sorties. The data in this column were required to compute the estimated yearly "Pave Spike operations extra costs" for each alternative system.

The "temporary duty" column contains the number of man days of TDY required for the alternative training systems. Only the ACMR system was assumed to have system associated TDY costs on a yearly basis. The man days are recorded in this table as an opportunity cost even though they are calculated as a dollar cost of the per diem paid to the personnel.

Comparison of System Dollar Costs

The incremental dollar cost data which were estimated for each alternative training system are presented as present values of seven years of operation in Table X on the next page. The present value estimates are provided for each alternative training system at four discount rates--zero, five, ten, and fifteen per cent--and three Pave Spike mean time between failure rates--eighty-five, fifty, and fifteen hours. The data in this table are calculated on the assumption that the number of dollars per year of operation required for each alternative system will be the same for that system over the seven years from 1974 through 1980. The present value figures for each alternative are calculated on the assumption that full operations of each system would start immediately in 1974.

The minimum acceptable mean time between failures (MTBF) of the Pave Spike pod is specified in Appendix E to be eighty-five hours of operation time. In the opinion of the writer, eighty-five hours is likely to be a high value of the MTBF which will actually be experienced in the field.

Table X. Present Values of System Incremental Costs with Varying Discount Rates and Pave Spike MTBF Values.

Discount Rate	ALTERNATIVES				
	1 BVT	2 LGB	3 PLGB	4 LMTS	5 ACMR
(MTBF = 85 hours)					
0%	$7,066,052	$67,800,202	$29,945,440	$ 988,731	$24,564,347
5%	6,133,333	58,850,574	26,045,236	875,233	22,807,434
10%	5,403,511	51,847,782	22,993,453	786,425	21,432,707
15%	4,830,151	46,346,280	20,595,925	716,656	20,352,699
(MTBF = 50 hours)					
0%	$7,343,119	$67,938,735	$29,945,440	$ 998,368	$24,633,619
5%	6,373,827	58,970,824	26,045,236	995,483	22,867,562
10%	5,615,388	51,953,723	22,993,453	892,366	21,485,680
15%	5,019,546	46,440,980	20,595,925	811,356	20,400,051
(MTBF = 15 hours)					
0%	$8,907,080	$68,720,715	$29,945,440	$1,780,345	$25,024,611
5%	7,731,345	59,649,580	26,045,236	1,674,239	23,206,943
10%	6,811,371	52,551,712	22,993,453	1,490,355	21,784,677
15%	6,088,625	46,975,517	20,595,925	1,345,893	20,667,323

Notes: 1. The PLGB incremental cost does not vary with respect to the MTBF value.

2. All costs are assumed to be incurred at the first of each year.

3. The data in this table are meant to be illustrative of the type and magnitude of costs expected to be associated with each alternative training system.

The values of fifty hours and fifteen hours were selected in order to explore the cost effects of a MTBF less than eighty-five hours. If the fifty hour MTBF were used, then the Pave Spike extra costs may be estimated as $57.04 per sortie by means of Equation (3) in Appendix E. Likewise, a MTBF of fifteen hours would produce an estimated cost of $190.03 per sortie. There may also be aircraft availability costs associated with a low Pave Spike system MTBF--the costs of increased turnaround time between aircraft sorties.

The assumption that full operations of each system would start immediately in 1974 will probably not be the actual case in the tactical air forces. A main reason for a delay would be the development and production time requirements of some of the training systems. In a comprehensive analysis, the effects of the development and/or production delay should be evaluated, both on the cost factor and on the effectiveness factor. The phase in rate of the Pave Spike acquisition and laser designator system could also influence the cost and the effectiveness of laser designator aircrew training during the first year or two of the time period. The Pave Spike phase in rate would probably be governed by the production rate of the Pave Spike pods, the availability of the aircraft to be modified, the amount of time required for the aircraft modification, and the location of the base where the aircraft modification would be accomplished. The Pave Spike system phase in rate could alter the tactical missions of some overseas units and require increased mobility commitments of units in the continental United States during the phase in period. Both of these factors could affect the costs of tactical air force operations. In any case, the effects of the shuffling of missions should be evaluated for the relevance and the magnitude of the associated costs.

Selection of the "Best" Alternative System

The Role of the Analyst

The role of the analyst in a military cost effectiveness analysis is to attempt to determine what the problem really is and what the objectives really are. His primary function is to attempt to reduce unknown consequences of choosing among future military courses of action. To accomplish this reduction he should be aware of all imbedded assumptions and subjective judgments in the analysis and he should test the analysis on its sensitivity to variance and modification of these assumptions and judgments. The analyst does not state conclusions or attempt to identify the "best" alternative, he merely presents the completed analysis to the appropriate decision maker.

The decision maker must resolve the problem on the basis of his judgment. Two types of judgment have been identified which are used by the decision maker. The two types are judgments of fact and judgments of value (Ref 43:33). A judgment of fact is a judgment about the value of some parameter or the degree to which some condition or criterion is met. One example of a judgment of fact is a judgment on how realism which is added by a proposed training system contributes to overall effectiveness of the tactical air forces. Another example would be a judgment about the degree of flexibility or of any of the sub-criteria in Chapter III associated with one of the alternative systems. A value judgment is a decision maker's judgment about his preferences for the performance mix of the alternative systems (Ref 43:33). The performance mix in this illustrative analysis could be a measure of how well each alternative system meets its stated objective and how well the stated

objective meets the real objective as measured by the personal value judgments of the decision maker.

The Role of the Military Decision Maker

The assumption of ceteris paribus, or all other things being equal, simplifies complex economic problems so that one part of the total environment may be examined in detail. There may be a danger in use of this assumption in a military cost effectiveness analysis unless there is effective, two way communication between the military decision maker and the analyst throughout the time that the analysis is being accomplished. Both the analyst and the military experts in the particular field have important roles to play in the military cost effectiveness analysis and decision making process.

In 1967, Mr. James R. Schlesinger stated that the value of the military man in cost effectiveness analyses was vested in his experience of command.

> Experience helps one to distinguish between superficially plausible hypotheses and the capabilities that will survive in the heat of battle. Command experience makes one keenly aware of the miseries of command and control, and the criticality of the human factor.
>
> . . .In examining new equipment or concepts, officers are not disposed to ignore man or man-equipment relations subsumed in organizations (Ref 34:205).

The actual selection of the "best" alternative system is the role of the military decision maker. In the illustrative analysis presented in this study, the best system is not necessarily the "cheapest" system. The decision maker should make judgments on all factors, such as the

factual judgments on the validity of the example of the sub-criteria evaluations presented in Table II. He should consider the spillover effects from the alternative systems and all possible alternative uses of the resources required by each alternative.

From the data presented in Table X, it may be seen that the laser monitoring/target scoring system is estimated to be the "cheapest" in terms of the present value of the incremental dollar costs regardless of the MTBF or the assumed discount rate. It also may be seen that the use of the inert laser guided bomb method is estimated to be the most expensive of the alternatives. Other factors may influence the final selection; such as the possibility that, for political reasons, no foreign government would allow operation of lasers over its territory. This restriction would automatically exclude the LGB, PLGB, and LMTS alternative systems from consideration. In this case, mixes of the five alternative training systems should be evaluated for feasibility.

Sensitivity Analysis

Sensitivity analysis is the name given to evaluation through systematic testing of the key assumptions to determine how uncertainty of the key assumptions affects the system costs (Ref 25:21). The object of the systematic testing is to determine if the revised analysis alters the tentative rankings and selections of preference. If it does, then the areas which alter the tentative selection should be examined closely to determine if the assumptions or judgments were reasonable and well founded. One by-product of this sensitivity analysis might be that it illuminates areas which need further study. Another by-product is that it may identify an area which would require close attention during the

early stages of implementation of a particular system. An example of the latter would be the acquisition and deployment of the Pave Spike laser designator system. Although the Pave Spike has been flown in combat, the first production models are not in general use in the Air Force.

Summary

The five alternative training systems presented in Chapter V were evaluated to determine estimates of their economic costs. The economic costs that were evaluated were the relevant costs that were not common to all alternatives. The economic costs were assigned to one of three system cost categories--research and development, initial investment, or annual operations.

The composition of the tactical air forces was assumed to be a worldwide total of twenty-one wings of tactical fighter aircraft. Seven of these wings were assumed to be tasked with laser guided weapons employment. The assumption was made that thirty aircrews from each wing were required to be qualified to perform as laser designator aircrews. Using the estimated sortie requirements of these designator aircrews examples of economic costs were computed for each alternative and compiled in Tables IX and X.

The role of the military decision maker and the analyst were discussed with respect to problems of military cost effectiveness analysis. No one alternative training system was identified as the best system.

Chapter VII

SUMMARY AND RECOMMENDATIONS

Summary

The primary purpose of this study was to attempt to develop a systematic approach or methodology which would help to identify optimal aircrew continuation training systems for use in the tactical air forces. The area of training for employment of laser guided weapons was selected to provide a realistic example for an illustrative analysis. Laser guided weapons are a recent addition to the tactical weapons inventory and firm aircrew continuation training procedures and semi-annual requirements have not yet been established.

Intuitively, the most effective tactical training must be that of employing real weapons in a combat environment. This can be simulated to some extent on a few practice weapons ranges in the United States today, however, this opportunity is available to only a few aircrews and this way of training is generally too expensive in the consumption of scarce resources.

The method suggested for use of identification, evaluation, and comparison of alternative continuation training systems is referred to as an economic cost effectiveness analysis. Research was conducted toward the establishment of a definite objective of the aircrew continuation training for the tactical air forces. This objective was determined to be to conduct training such that a level of individual

and unit combat readiness could be maintained which would allow the tactical air forces to be capable of destroying or neutralizing an enemy. In an attempt to quantify and bound this objective, a simplifying assumption was made that the individual tactical air force commanders possessed adequate experience and judgment to know what level of competence would likely be required of their aircrews in a combat theater. The commanders would then be required to insure that their aircrews were competent to perform at this level.

Existing measures of aircrew training and training effectiveness were discussed. A method of measurement of the effectiveness of a continuation training system was developed for the purpose of this study. It is the number of events using a particular training system which should allow for maintenance of the combat competence at a reasonable level for the average aircrew. Hypothetical examples of how this number of training events could be objectively determined were presented. Use of the examples requires subjective inputs from experts in the field in order to transition aircrew training from the combat environment to the peacetime environment.

Personal interviews were conducted with experts in the fields of tactical aircrew training and combat employment of laser guided weapons. The data acquired from these interviews were used to identify possible alternative methods of training and to provide estimates of how much of each method would be required to maintain a reasonable level of combat readiness.

A group of ten sub-criteria was presented which could be used to evaluate proposed tactical aircrew training systems for desirability. These sub-criteria should be applicable for use of evaluation of any

tactical aircrew training system.

Five methods of aircrew training were subjectively identified as possessing the capability of the maintenance of a reasonable level of aircrew and unit combat readiness. Each of the five methods was predicted to require slightly different numbers of sorties or weapons to maintain this level of combat readiness. Each of the five alternatives was subjectively evaluated with respect to the ten sub-criteria and an example of an alternative desirability array based on this evaluation was provided in Table II.

The relevant economic costs of each of the five alternatives were evaluated and illustrated with examples of the estimated costs. Where these costs had an opportunity cost which was more relevant than the dollar cost, the oppotunity cost approach was used. The relevant dollar costs which would be required for the development, procurement, deployment, and operation of each alternative training system were estimated and listed. When all dollar costs were determined, they were presented in a table which indicated the sensitivity of the dollar analysis to several discount rates. The estimated opportunity costs were presented in a similar table. The sensitivity of the illustrative analysis to the MTBF of the Pave Spike system was investigated at MTBF rates of fifteen, fifty, and eighty-five hours.

The role of the analyst does not include stating conclusions drawn from an analysis. The military decision maker must select the alternative which corresponds with his personal judgments of the factors associated with a decision.

Recommendations

Although the stated purpose of this study was to develop a methodology and not to conduct a specific analysis, the writer submits that the elements presented herein are relevant to the area of evaluation of aircrew training systems for employment of tactical laser guided weapons. The assumption that the designator aircrew is the critical element in the effective employment of laser guided weapons was based on statements from the interviewed aircrew members. The approach that only some aircrews be tasked with maintaining laser designator combat readiness seems to be a valid approach and the writer suggests that more research be conducted in this area. This research should also cover the feasibility of identifying laser designator aircrews with speciality code identifiers so that their reassignments could be monitored at Air Force level. This monitoring would be most important for the weapons systems operators skilled in the operation of the laser designator systems.

The central problem in the effective evaluation of tactical aircrew training systems is the determination of a suitable means of measuring the effectiveness of the aircrew training. Attempts to measure the effectiveness of aircrew training are usually based on subjective evaluations of individual and unit proficiency.

There is a definite need for an effective criterion (or criteria) with which to measure aircrew effectiveness. A good criterion measure would aid in the evaluation of the aircrew training systems and in the determination of the combat readiness of the tactical air force. In the opinion of the writer, there is no adequate criterion measure of aircrew training effectiveness in use today.

The method proposed in Appendix B to this study should be investi-

gated for its feasibility. Further study should be conducted in the subject of measurement of aircrew combat readiness. It is not clear to the writer why 140 feet should be an acceptable CEA for dive bombing instead of 120 feet or 160 feet. As resources available to the military dwindle, it will become more important to insure that the measures that the tactical air forces are using are meaningful and realistic with respect to the mission of the tactical air forces.

The Pave Spike acquisition and laser designator system is likely to be the major laser designator system used in the Air Force for the next ten years. The life cycle costs of this system should be evaluated in order to determine the operational costs of future years which could affect the level of future aircrew training.

The large investment required for some training systems (e.g., the ACMR) invites research to determine if it is possible, or practical, to fully utilize the training facilities to minimize the fixed overhead costs per user. In other words, locate the fixed training locations in a central location so that they may be used by several different wings and operate the system as many hours per day as practicable.

Research should be conducted to determine the feasibility of modifying a flight simulator so that it would be capable of providing some level of aircrew training for employment of laser guided munitions. It may be that a specialized simulator could be developed especially for the training of aircrews in the employment of sophisticated air-to-ground weapons.

Investigation of the methods of measurement of spillovers of tactical aircrew training systems should be conducted. For example, the ACMR system should have significant spillover in the areas of weapons

and tactics testing as well as in the area of combat readiness evaluation of entire units.

In summary, the opinion of the writer is that use of the methodology developed in this study should allow a military agency to conduct a similar analysis which--through the use of classified force structure data, comprehensive input data from expert aircrew members, and validated cost estimates--would produce a meaningful evaluation of alternative tactical aircrew training systems.

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APPENDIX A

WEAPONS RANGES

Weapons Ranges

This appendix contains information pertaining to the use of weapons ranges for aircrew training. Most methods of aircrew training for employment of air-to-ground weapons require the use of weapons ranges. A weapons range is an area of real estate with practice targets located on it where bombs actually may be dropped. Entry to the real estate and the air space above it to a certain altitude is restricted to all but authorized military users.

There are two general types of weapons ranges that are suitable for practice for employment of laser guided munitions. The two types are the air-to-ground conventional range and the tactical range. Additionally, either the conventional range or the tactical range may be designated as a "laser cleared range" and may be near, or co-located with, an "electronic warfare range."

Air-to Ground Conventional Range

The air-to ground conventional range is a weapons range which contains suitable surface targets against which practice bombs, rockets, or automatic weapons fire may be directed. This type of weapons range normally has the capability to provide impact scores for all types of weapons (Ref 8:2-1). Each tactical fighter unit presently has access to a conventional weapons range for the required aircrew requalification and continuation training.

The minimum size for a conventional range is four by six nautical miles (Ref 8:2-3). The targets are fixed, well marked, and easily discernable from the air. The aircraft attack headings are limited and strictly enforced as target maintenance and scoring personnel are located in close proximity to the targets. The separation distance between the firing aircraft and range personnel varies from 600 feet for automatic weapons (cannon) attacks to about 3000 feet for bomb and rocket attacks (Ref 8:2-6).

Numerous ground markings are provided for safety purposes. These markings may be lines formed by spacing white painted tires or barrels, or they may be lengths of freshly plowed ground. The markings are provided to indicate the location of personnel, the correct attack headings, and the visual cues which are used by aircrews to compensate for wind effects on the bombs.

Tactical Range

The tactical range consists of an area which contains realistic surface targets. These targets may be truck convoys, airstrips, or missile sites against which weapons may be employed in the practice of tactical weapons delivery concepts (Ref 8:2-2). There are fewer tactical ranges available today than there are conventional ranges. The primary advantage of the tactical range is that it gives aircrews the opportunity to locate and attack targets which appear as they might be found in a combat area.

Tactical ranges are required to have a minimum size of five by ten nautical miles, although a tactical range this small may restrict the tactical flexibility of realistic training (Ref 8:2-3). In the inter-

est of flying safety, minimum allowable altitudes and airspeeds are normally higher on tactical ranges than on conventional ranges. Tactical ranges normally do not possess the capability for providing the weapon miss distances necessary for the periodic aircrew weapons qualification and recertification. Until this scoring capability is provided on tactical ranges, this function must be fulfilled by the conventional ranges.

Laser Cleared Range

The operation of a laser illumination device from an aircraft is restricted for safety reasons. One of the primary safety concerns is reflection of the laser light from water or other external reflecting surfaces (Ref 5:10-13). There is a slight possibility that strong laser energy may be harmful to humans who happen to be illuminated by a laser light source. To prevent this, laser designators are not allowed to be fired below 5000 feet above the ground in daylight conditions and below 10,500 feet at night (Ref 37:16).

Safety standards will have to be developed to determine if a conventional or a tactical range would be safe for laser operations. A weapons range which has been approved for laser operations will be referred to as a "laser cleared" range in this study.

Electronic Warfare Range

Electronic warfare is a term used to indicate operations in the electronic environment of hostile airspace. To survive and operate effectively in this environment, aircrews must be provided the oppor-

tunity to practice operations in simulated, realistic electronic warfare (EW) airspace. This actice is provided by frequent flights in what is known as an EW range. An EW range is simply a volume of airspace where the hostile electronic environment is simulated.

The EW range may be located over or near a weapons range complex and it is expected that, in the future, there will be enough EW ranges so that EW training can be routinely conducted while on the weapons range as well as to and from the range (Ref 8:4-12). The EW range will simulate various threats to the airborne aircraft and the aircraft will be required to react accordingly, while continuing on their assigned mission.

Summary

Conventional and tactical weapons ranges are utilized to provide the tactical fighter aircrew with practice targets against which munitions may be expended. Conventional ranges are well marked and are used for necessary aircrew weapons qualification purposes while tactical ranges are used to provide realism to the training. All ranges will have to pass certain criteria related to laser safety before operations with laser illuminators will be allowed. Electronic warfare ranges may be located near or above the other types of weapons ranges.

APPENDIX B

A PROPOSED METHOD OF MEASURING THE EFFECTIVENESS OF LASER TASKED AIRCREWS

A Proposed Method of Measuring the Effectiveness of Laser Tasked Aircrews

This appendix presents a proposed method for objectively measuring the effectiveness of laser guided weapons training accomplished by aircrews tasked for employment of laser guided weapons. The proposed method requires expenditure of BDU-33 practice bombs coupled with video tape assessment of the laser designator aim point during the time of flight of the bomb. The BDU-33 can be dropped on any type of weapons range as long as the circular error (CE) of the impact can be scored. The laser gun does not have to be fired as long as there is some way of correlating the bomb time of flight with the video tape.

Aircrew Functions Measured

If laser guided bombs (LGB's) are assumed to be one hundred per cent reliable mechanically, then the accuracy of laser guided bombs may be assumed to be completely dependent upon two aircrew functions. The first is the function of positioning the bomber aircraft such that the LGB is released within the basket of required parameters. It is physically impossible for the LGB to arm and hit the desired impact point if it is released outside of these parameters. For the purpose of the discussion in this appendix, a "hit" is defined as a LGB which actually guides and impacts within a certain circular error distance from the desired impact point. A "miss" is any LGB which impacts outside of a circle around the desired impact point with a radius greater

than the hit circular error distance. A realistic CE for a LGB might be in the vicinity of thirty to forty feet.

The second function is the laser illumination of the desired impact point itself. For the purpose of this discussion, it is assumed that the laser illumination is measured as the per cent of the bomb time of flight that laser energy of the required intensity is on the desired impact point. This will be referred to as "per cent laser illumination time" or "PLIT" in this appendix. The second function is important as the LGB is designed so that it is constantly seeking laser energy and correcting its ballistic flight path until it impacts with the ground.

Although these two functions are performed completely independently of one another, they are interrelated with respect to the effectiveness of the LGB delivery when measuring the distance of the actual CE. For example, if the LGB were dropped in the "center" of the basket then it could hit the desired impact point with no laser energy required to correct its flight path. It is rare in combat that a fighter bomber aircrew has the luxury of the amount of time which is normally required to position the aircraft such that the bombs will ballistically fall directly on the target. If the LGB is released at any other point in the basket, some amount of laser energy is required to guide the bomb to the target. The closer the actual release point is to the "edge" or the "side" of the release basket, then the higher the PLIT must be in order to insure a certain probability of a hit.

The Measure of Effectiveness

The probability of a hit is the measure of effectiveness provided

by the method proposed in this appendix. The two inputs required for determination of the probability of a hit are the actual CE of the BDU-33 practice bomb and the PLIT that the designator aircrew achieved. These two factors could be plotted on the two axes of an ordinary two dimensional graph such as the one in Figure 8 below. Values on the

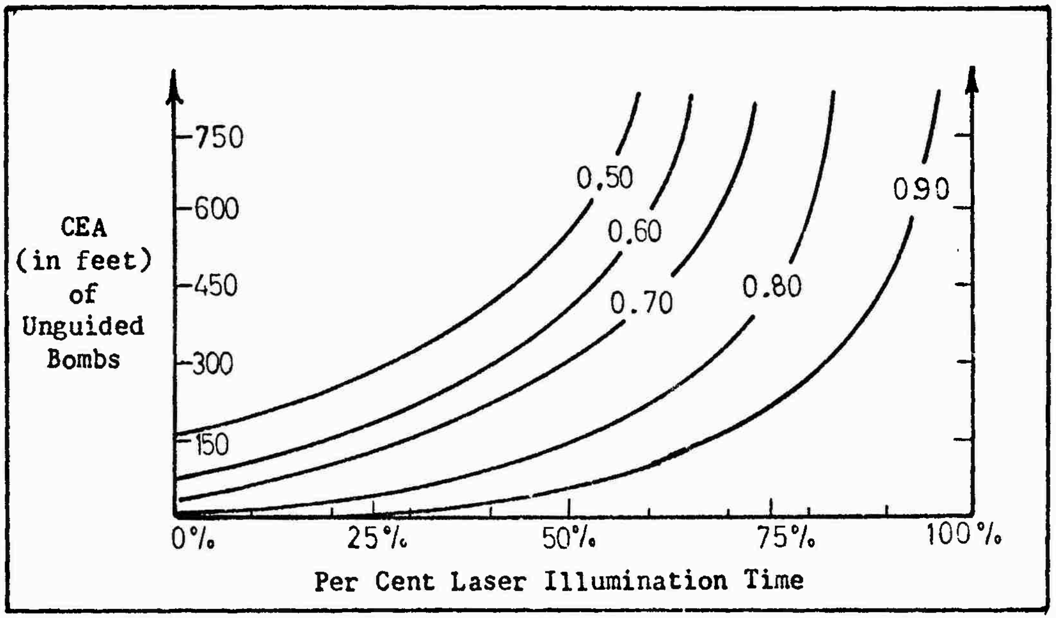


Figure 8. Hypothetical Probability of Hit Curves.

vertical axis would be the circular error average (measured in feet) of LGB's if they were to go ballistic or of BDU-33 practice bombs. Values on the horizontal axis would be the per cent laser illumination time where the time is measured as the time of flight of the bombs. The scale on the horizontal axis would vary from zero to one hundred per cent. This graph may be entered with either the CE of an unguided practice bomb or the per cent laser illumination time. From the one entry point it is possible to determine what per cent laser illumination time (or circular error) would give the desired probability of a hit.

The hypothetical curves on the graph in Figure 8 represent a family of "probability of hit" curves. For example, if a practice bomb was dropped with a CE of 150 feet and the per cent laser illumination time was measured to be fifty per cent, then it may be said from reading the graph in Figure 8 that the probability of a hit with that bomb was close to 0.80. If the PLIT was measured to be seventy per cent, then the probability of a hit would be closer to 0.90 for the same bomb. An example of entry from the horizontal axis would be where a tactical unit had achieved an average PLIT of sixty-five per cent on all missions flown during an inspection. To determine what CEA the unit would have to maintain to achieve a 0.65 probability of hit, the inspectors would interpolate between the 0.60 and the 0.70 probability curves and read the CEA from the vertical axis. In this graph it would be about 600 feet.

Construction of the Graph

In order to plot the probability of hit curves, data would be required where actual LGB's were dropped under test conditions and the per cent laser illumination time data were computed. Data plotted in the vertical direction would have to be procured from actual histories of past releases of LGB's under conditions where the actual parameters of the bomber aircraft were measured at the instant of bomb release. Data plotted in the horizontal direction would have to be procured from histories of actual releases where the laser illumination measurement was accomplished in correlation with the time of flight of the LGB's.

As these data are collected, they should be grouped into random groups of equal size, such as groups of ten LGB's. The CEA and the

average PLIT could then be computed for each group of ten LGB's. If seven of the ten bombs in one particular group had been hits, then the point on the graph formed by the intersection of lines drawn from the CEA and PLIT values for the ten bombs would correspond to a probability of hit of 0.70. Iteration of a number of groups of ten bombs should enable an analyst to develop a graph such as the hypothetical graph illustrated in Figure 8 by fitting curves to the equal probability of hit points.

Examination of the curves in Figure 8 illustrates some points which seem to be intuitively correct. If a bomb were dropped so that its ballistic CE were less than thirty feet, then it might be expected that varying the PLIT would not significantly increase or decrease the probability of a hit. If the bomb was dropped where the ballistic CE would be 500 feet, then it may be seen from the graph that by increasing the PLIT from fifty per cent to ninety per cent the probability of a hit should increase from close to 0.53 to close to 0.90.

Combat Application

A graph like Figure 8 could be used for evaluation of the combat competence of either an individual aircrew or an entire unit for operational readiness inspections. The CEA of ordinary practice bombs could be computed by existing methods of scoring while the PLIT could be computed by post flight evaluation of the video tape recordings from the designator aircraft. From these two points on the axes of the graph the probability of hits could be objectively determined and reported as a measure of the effectiveness of the individual or the unit.

A graph could also be drawn for LGB releases in a combat environ-

ment if enough data were available. It is likely that the probability of hit curves would shift down to the right as illustrated by the hypothetical curves in Figure 9. This shifting would be due to the fact that many aircrews devote attention to other factors during employment of weapons in combat and do not concentrate quite as much attention to precise weapon delivery as they do in a friendly environment. These other factors include "jinking" the aircraft to prevent being tracked easily by anti-aircraft weapons, maintaining the desired flight position for purposes of electronic warfare protection, and the general increase of tempo of the combat environment over highly defended target areas.

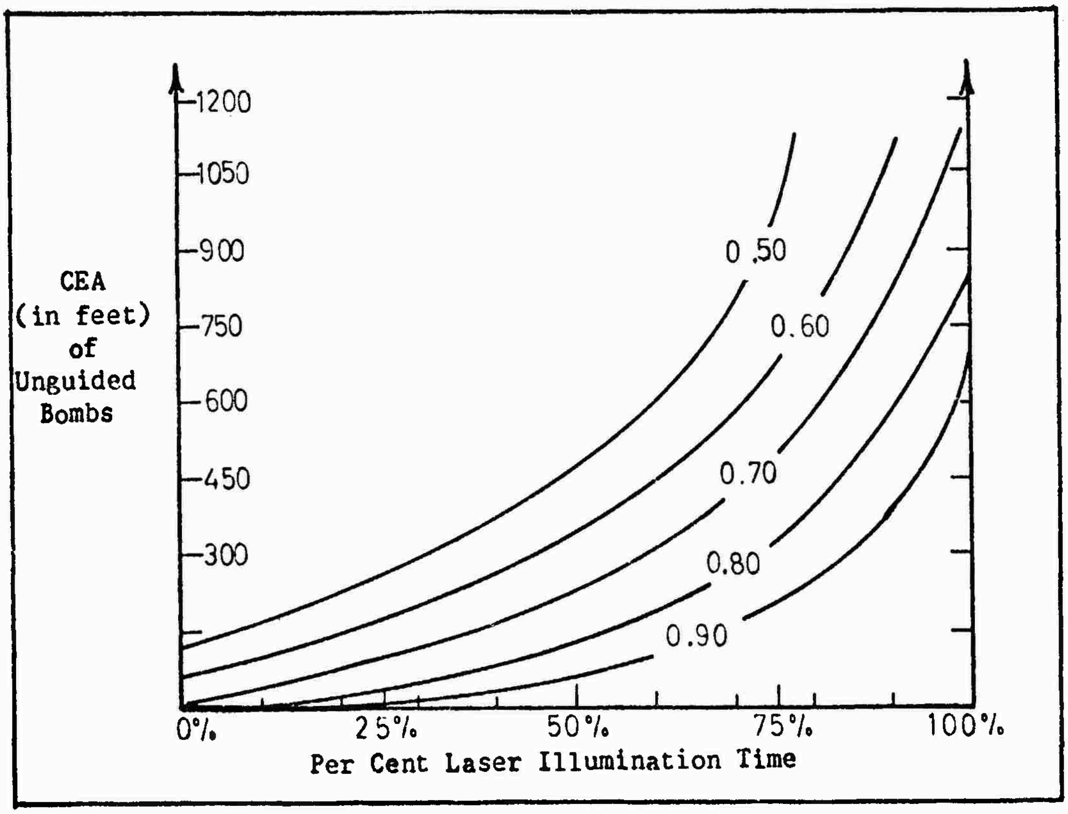


Figure 9. Hypothetical Probability of Hit Curves for Combat Employment of Laser Guided Weapons.

Summary

In summary, it should be possible to provide a means for objective measurement of the effectiveness of laser tasked aircrews if data were procured from past measured LGB drops. The inputs required are the measured circular error of the BDU-33 practice bomb and the per cent illumination time achieved by the laser designator aircrew. The measure will be reported as the probability of a hit per LGB dropped.

APPENDIX C

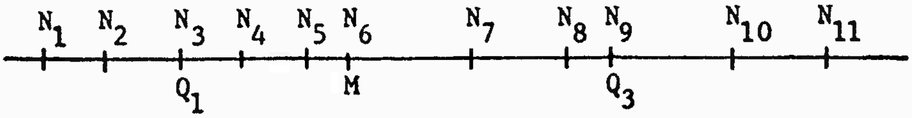
THE DELPHI TECHNIQUE

The Delphi Technique

This appendix contains a discussion of the Delphi technique of forecasting or estimating. The Delphi technique has been designed to improve the estimates that are obtained from groups of experts in a particular field. Through the means of statistical aggregation of opinions of experts provided by the Delphi technique, the analyst should be able to objectively determine an estimate which represents the collective opinions of all the experts who responded.

The form and application of the Delphi technique may be described as follows:

> The Delphi technique attempts to improve the panel or committee approach in arriving at a forecast or estimate by subjecting the views of individual experts to each other's criticism in ways that avoid face-to-face confrontation and provide anonymity of opinions and of arguments advanced in defense of these opinions. In one version, direct debate is replaced by the interchange of information and opinion through a carefully designed sequence of questionnaires. The participants are asked not only to give their opinions but the reasons for these opinions, and at each successive interrogation, they are given new and refined information, in the form of opinion feedback, which is derived by a computed consensus from the earlier parts of the program. The process continues until further progress toward a consensus appears to be negligible. The conflicting views are then documented.
>
> . . .Consider the common situation of having to arrive at an answer to the question of how large a particular number N should be. (For example, N might be the estimated cost of a measure, or a value representing its overall benefit, or the portion of a budget to be devoted to a measure.) One might proceed in the following steps: (i) Have each expert independently give an estimate of N. Arrange the responses in order of magnitude, and determine the quartiles, Q_1, M, Q_3 so that the four intervals formed on the N-line by these three points each contain one quarter of the estimates.



> (ii) Communicate the values of Q_1, M, Q_3 to each respondent, ask him to reconsider his previous estimate and, if his new estimate lies outside the interquartile range (Q_1, Q_3), to state briefly the reason why, in his opinion, the answer should be lower (or higher) than corresponds to the 75 per cent majority opinion expressed in the first round. (iii) The results of this second round (which as a rule will be less dispersed than the first) are again fed back to the respondents in summary form, including the new quartiles and median. In addition, the reasons for raising or lowering the values, elicited in Round 2 and suitably collated and edited, are also given to the respondents (always, of course, preserving anonymity as to the proponents). Now the experts are asked to consider these reasons, giving them the weight they think they deserve, and, using the new information, to revise their previous estimates. Moreover, if the revised estimates fall outside the second round's interquartile range, the respondent is asked to state briefly why he found unconvincing the argument that might have drawn his estimate toward the median. (iv) Finally, in a fourth round, both the quartiles of the third distribution of responses and the counterarguments elicited in Round 3 are submitted to the respondents, who are encouraged to make one last revision of their estimates. The median of these Round 4 responses may then be taken as representing the group position as to what N should be (Ref 29:11-12).

The writer suggests that the Delphi technique could be used effectively in conjunction with the trade-off approach presented in Chapter II of this study. After the trade-off between actual combat weapons employment and the alternative training system is accomplished, each expert is likely to have determined different values of the number of units of a training system which would be required to maintain a reasonable level of aircrew combat competence.

The number N discussed above could be the estimate by a Delphi participant of the number of hours or sorties of a particular method of

training which would be required to maintain combat readiness for one aircrew over a six month period. The experts should be asked to consider the possible constraints which will be present in peacetime training operations when they make their estimates. These constraints should include the probability that the aircrews will be tasked for maintaining individual combat readiness status in several mission areas and thus will have to allocate a fixed amount of flying time among all of these mission areas.

In summary, the Delphi technique is an approach which may be used to improve the estimates of groups of experts. Iteration of each survey will be accomplished and provided so that all the participants can either stand fast and defend their estimate or change their estimate. It is possible that the Delphi technique could be helpful in the analysis of tactical aircrew training systems.

APPENDIX D

DISCUSSION OF AIRCREW MEMBER INTERVIEWS

Discussion of Aircrew Member Interviews

This appendix contains a discussion of the backgrounds of the aircrew members interviewed by the writer, a list of some questions that were common to all aircrew member interviews, and a discussion of some of the responses to the questions.

The individuals selected for interviews were aircrew members who had previous combat experience with one or more of the three laser designator systems discussed in this study--Paveway I, Pave Knife, or Pave Spike. It was necessary for the writer to identify the aircrew members through personal contact since the Air Force has no specific personnel identifier to flag aircrew members who have combat experience with laser designator systems. The ranks of the individuals ranged from captain to lieutenant colonel. Included in the group were two senior officers who had recent combat experience with all three laser designator systems. One of these individuals had been performing as a squadron commander and the other as a squadron operations officer in Southeast Asia when they were employing laser guided weapons. Most of the pilots interviewed had been both flight leaders and laser instructor pilots in their laser tasked units.

All personal interviews were conducted to obtain only unclassified data. Each individual was requested to assume that he was at the command level in the tactical air forces and he was faced with determining the most acceptable number of sorties or other units of a training system which would enable him to maintain the combat readiness of his air-

crews at a reasonable level. The area of training to be evaluated was stated to be employment of laser guided weapons. The aircrew members were informed that they would likely have a maximum of only twenty flying hours per aircrew per month and that they would also be tasked with maintaining combat readiness in some other mission areas.

After the information above was conveyed, each aircrew member was asked several questions which required subjective answers. The questions listed below were common to all the interviews.

1. If you were in a combat area, how many sorties would you require per aircrew per six months to maintain a minimum, reasonable level of combat competence in the employment of laser guided weapons?

2. Now, if the (BVT, LGB, PLGB, LMTS, or ACMR) alternative training system was available in peacetime, how many sorties or events do you think would be required per six months in order to maintain the same combat ready status of your aircrews?

3. If you were only allowed to fly (half of the number in the first question) laser guided weapons sorties in a combat area, how many units of the alternative training system (if it were available) would you require to replace the sorties you lost and maintain the same effective level of aircrew competence?

4. Can you think of any other method or system that might be capable of maintaining combat readiness for employment of laser guided weapons?

Each of the alternative training systems presented in Chapter IV was identified and explained prior to asking the second question above. The sequence of the first three questions was planned so that the tradeoff approach presented on page twenty-eight of this study could be used.

All of the aircrew members interviewed stated that the effectiveness of laser guided bomb employment was driven by the skill of the laser designator WSO and the flight tactics used in the target area.

Several pilots stated that practice of flight tactics was so important that they would accept some missions without any bombs if they could practice flight tactics on a tactical weapons range. Most aircrews stated that most, if not all, practice missions should be flown on tactical ranges. All considered video tape necessary for any method of training.

The estimates for the minimum number of combat sorties per six months required to maintain a reasonable level of combat competence ranged from six to fifty-two with the mean at twenty-four or about one per week. The number of training sorties in peacetime averaged a little over twelve depending on what alternative system was being considered.

In response to the third question all aircrew members provided a number of units of the alternative training system such that the trade-off ratio was constant or nearly so. In other words, the curve connecting the two axes is likely to be a straight line.

The data and impressions obtained from these interviews were used by the writer to provide the input data for the illustrative analysis conducted in this study. All references to aircrew members in the text of this study refer to the aircrew members as identified in this appendix.

APPENDIX E

EVALUATION OF THE COMMON COST ELEMENTS

Evaluation of the Common Cost Elements

This appendix contains discussions and illustrative evaluations of the common cost elements applicable to the five laser guided weapons alternative training systems.

Pave Spike Costs

Operation of the Pave Spike acquisition and laser designator system is common to all five alternatives. The initial investment required to equip and maintain a seventy-two aircraft fighter wing with thirty-six Pave Spike pods for one year is presented in Table XI below. The cost data in this table are taken from a TAC study and are given in 1972 dollars. The aircraft is the F-4. The initial Pave Spike investment is considered to be a sunk cost in this study and the annual operating costs are considered to be irrelevant insofar as they are common to all alternatives.

Table XI. Pave Spike First Year Cost per F-4 Wing (Ref 36:C-3).

Aircraft Mod ($20,000 each)	$ 1,440,000
Aerospace Ground Equipment/Facilities	334,000
Number of Additional Munitions/ Maintenance Personnel	(18)
One Year Wages for Additional Personnel	141,000
Pave Spike Pod ($120,000 each) One per Two Aircraft	4,320,000
TOTAL	$ 6,235,000

From the estimated data in Table III in Chapter V, it can be calculated that each wing will have to fly at least 720 designator sorties per year in order to maintain combat readiness of designator aircrews. All designator sorties over 720 sorties for any alternative training system represent a relevant cost for that alternative, that of the cost of the extra Pave Spike system operation time. In order to measure the cost of the extra Pave Spike system operation time, it is assumed that the average system operational time is fifty-five minutes or 0.92 hours per sortie. This amount of time includes pre-flight checks and the actual in-flight operation.

It is assumed that the cost of the extra Pave Spike system operations time is equal to the sum of the costs associated with failures of the pod due to the extra operations time required by some alternatives. The estimated cost of the man hours required to repair are included, as it is assumed that personnel manning will be dependent upon the workload imposed by operational requirements.

The development specification for the Pave Spike system requires the mean time between failures (MTBF) of the pod to be 125 operating hours and the minimum acceptable MTBF to be 85 operating hours (Ref 40:38). The figure of 85 hours MTBF will be used in this analysis. The same document requires that at organizational level the mean time to repair (MTTR) the pod will be 1.5 hours while the maximum time to repair will be 3.0 hours. The field level shop MTTR is specified to be 8 hours while the maximum time to repair is specified to be 16 hours (Ref 40:39). The writer is not aware of any data available at this time to indicate the probable mix of organizational level and field level repair, or the average cost of replacement and discard units.

For the purpose of this study, the simplifying assumption is made that the average labor cost to repair the Pave Spike is equal to the average hourly cost of five personnel for a MTTR of five hours per failure. In addition, the material cost per failure is assumed to be $3000. The five personnel include the supervisory and the support personnel. The five hours MTTR is meant to compensate for the unknown future mix of organizational and field level repairs.

From Table XI, the average cost for one man hour of work is assumed to be roughly $4.00, if the average man works 2000 hours per year. The average personnel cost and material cost per Pave Spike failure may then be estimated as:

$$\begin{aligned} \text{Cost per failure} &= (\text{Material cost}) + (\text{MTTR})\ (\text{man hour cost})\ (\text{personnel required}) \qquad (1) \\ &= \$3000 + (5 \text{ hours})\ (\$4/\text{man hour})\ (5 \text{ men}) \\ &= \$3100 \end{aligned}$$

The number of Pave Spike failures per sortie may be estimated as follows:

$$\begin{aligned} \text{Failures per sortie} &= \frac{\text{Operate time per sortie}}{\text{MTBF}} \qquad (2) \\ &= \frac{0.92 \text{ hours/sortie}}{85 \text{ hours/failure}} \\ &= 0.0108 \end{aligned}$$

From equations (1) and (2) above the cost of Pave Spike operation per sortie due to system failure may be estimated as:

$$\begin{aligned} \text{Operation cost per sortie} &= (\text{cost per failure})\ (\text{failures per sortie}) \qquad (3) \\ &= (\$3100)\ (0.0108) \\ &= \$33.48 \end{aligned}$$

A simple test of the sensitivity of the cost per sortie to the MTBF may be accomplished by varying the value of the MTBF in equation (2) and computing the results in equation (3). For example, a MTBF of 50 hours would give an estimated cost per sortie of $57.04 while a MTBF of 15 hours would give an estimated cost per sortie of $190.03.

There also is a cost of flying the aircraft associated with an ineffective sortie due to Pave Spike system failure. However, since this flying time is assumed to be counted as contributing toward that aircrew's yearly requirements, it will probably be taken out of some other area of training and will not be assigned a dollar cost in this analysis.

The additional handling and operation of the Pave Spike pods required by some alternatives should accelerate the aging of the pods. The quantification of the cost of the aging effect will not be attempted in this study, but should be considered in a comprehensive study when aging data on the Pave Spike pod is available.

The normal attrition due to accidents and aircraft losses is assumed to be the same for all alternatives and will not be considered as a dollar cost in this study. This is in line with the standard cost estimating procedure where the mission equipment will be out of production. In these situations, the attrition continues and the equipment is simply not replaced (Ref 27:III-21). However, if any alternative could be predicted to increase or decrease the normal attrition rate, this would be a very important cost (or benefit) of that alternative. Even in the case of mission equipment still in production, any attrition of high value resources, such as personnel or aircraft, impacts on the combat readiness of the tactical air forces.

Aircraft Opportunity Cost

It is possible to compute an average cost per hour of flying time by dividing the total number of dollars required to equip, maintain, operate, support, and pay the tactical air forces over a period of time by the total number of flight hours flown during the same period of time. The average cost per flying sortie could be computed in the same manner. The dollar figure which could thus be calculated is an average cost for only that particular level of operations. If the total flying hours were to be increased or decreased, the total number of dollars consumed may or may not increase or decrease in proportion to the flying hours. The probable result would be that the previously computed cost of the average sortie or flight hour would be erroneous for the new level of operations.

If the level of operations were assumed to be fixed at some level, as has been assumed for this study, then the only meaningful cost which could be assigned to a flight hour or sortie would be an opportunity cost. That is; to what other use could this sortie or hour of flight time be applied and what would be the value of that application? It is difficult to determine universal categories or classes of alternate uses of tactical fighter flying hour resources. For example; to one wing commander, the most important alternative use may be that of air-to-air combat training while another wing commander may value low level navigation training higher than any other training area.

In an effort to establish an initial basic measure of the opportunity cost of flying time, two basic categories are selected--operational training and operational support. Operational training flying time should have a high level of spillover for other training objectives. For example; the bomber aircrews, although supporting the designator

aircrews, should be able to accomplish some effective training for their own requirements. Operational support flying time would be that flying time required for an alternative which has a low level of spillover for other objectives. For instance; the flying hours consumed on aircraft ferry flights provide little opportunity for productive training.

In this study, the operational training flying time will be measured in numbers of sorties and will be sub-divided into bomber sorties and designator sorties. The estimated sortie requirements of each alternative will be calculated for the total tactical air forces on a yearly basis.

TDY Costs

All costs that may be attributed to TDY for aircrew training are relevant costs and most can be estimated. Quantifiable TDY costs include per diem payments, travel payments, aircraft flying time to the TDY base, and other costs incurred to support personnel and equipment transportation. Although all alternatives but the basket and video system may require TDY, only the ACMR alternative will be assumed to require TDY in this study.

For the purpose of this study, it is assumed that the TDY bases for any wing are no more than a two hour flight from the home base. This is equivalent to a distance of about 800 nautical miles, which is plausible in PACAF, TAC, and USAFE. Each aircrew will be assumed to be required to go on a three week TDY once each six months. During a three week TDY, the aircrew will normally have an opportunity to fly fourteen days and will be able to fly twice daily if necessary. The amount of training time provided from this amount of TDY should be adequate to ful-

fill the estimated continuation training requirements.

Normally, aircraft are rotated between the home air base from which the TDY training operations will be conducted. These ferry flights are accomplished in order to allow each aircraft to undergo periodic maintenance requirements at the home base. It is likely that each aircraft in a fighter wing will be rotated each year in order to accomplish these maintenance functions. For this study, it is assumed that each wing which has to accomplish TDY for ACMR training will ferry thirty-six aircraft each six months for a total of seventy-two aircraft each year. A total of 144 ferry sorties are required to enable all seventy-two aircraft of one wing to fly to the TDY base and back again once per year. The amount of flying time required to fly one sortie is estimated to be two hours. Thus, the total flying time per year per wing for ferry flights may be calculated to be twice 144, or 288 flight hours.

All eighty aircrews are assumed to be assigned to TDY for training twice per year, but only thirty-six aircrews will be able to fly in the aircraft each six months. The remaining forty-four aircrews are assumed to travel with the support personnel on military airlift. The average round trip cost of the military airlift is assumed to be seventy dollars per person. This figure is meant to include a pro-rated share of the transportation costs of the associated equipment necessary to operate from the TDY base.

The number of days on TDY is estimated to be nineteen days for the aircrews who ferry the aircraft and twenty-one days for the other personnel. This latter figure provides for the normal overlap for the ground personnel.

Over a six month training period, 380 non-flying support and maintenance personnel are assumed to be assigned to one twenty-one day TDY. With the additional eighty-eight aircrew members from the forty-four aircrews, the total number of personnel transported by military airlift is 468. The number of man days of TDY per wing per six months is equal to the sum of the aircrew nineteen day TDY periods and the other personnel twenty-one day TDY periods. This sum is 11,196 man days per six months or 22,392 man days per year. The average daily costs of military TDY in additional pay and allowances is assumed to be ten dollars per person.

Weapons Range Costs

There are economic costs associated with the different alternative requirements for training time on the weapons ranges. The estimation of these costs is very much dependent upon the location of the weapons range with respect to the fighter wing and to the number of other users of the weapons range. The simplifying assumption is made for the purposes of this study that all local ranges are cleared for laser operations and all seven laser tasked wings possess adequate tactical weapons ranges.

The total range periods estimated to be required per wing per year for the first four alternatives are 630,540, 480, and 570 periods, respectively. These numbers are computed from Table III. Most weapons ranges are available for sixteen thirty-minute periods per day (Ref 8: 6-1). Thus, the weapons range requirements for laser guided weapons training may be estimated to be about 40, 34, 30, and 36 days of operation per year, respectively. These range requirements would be spread out over the whole year and are the requirements for only one

wing.

A weapons range is normally expected to be open for almost 4000 thirty minute periods per year (Ref 8:6-1). If the range periods were not utilized for laser guided munitions training, then they would be available for other, alternative uses. It is difficult to assign a dollar value to best represent the value of the alternate use. For this reason, the economic costs associated with the use of the weapons ranges for these four alternatives will be reported as spillover costs (or benefits) in terms of numbers of range hours required per year. It will be necessary to report the total number of weapons range hours as the ACMR system does not require use of a normal weapons range.

Summary

The cost of the Pave Spike system extra operations time was estimated to be $33.48 per sortie for a MTBF of 85 hours. This figure is based on the assumed personnel costs and the assumed cost of materials required to repair each failure. The cost of aircraft operations required for each alternative method of training will be estimated as an opportunity cost. The two basic categories of this opportunity cost will be operational training and operational support.

The costs of TDY required by an alternative training system are relevant costs. The TDY will be assumed to be required only for the ACMR system. Only four wings are assumed to require TDY for use of the ACMR system. The costs associated with the use of the weapons ranges are not estimated due to the difficulty in determining the alternative use of the resources. Thus, the costs of the weapons ranges will be reported as hours of range operations required per year for each alternative training system.

VITA

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13. ABSTRACT

This study is directed toward development of a methodology to help identify optimal aircrew continuation training systems for use in the tactical air forces. The area of training for employment of laser guided weapons was selected to provide a realistic example for an illustrative cost effectiveness analysis. Data obtained from inter - views with fourteen aircrew members with laser combat experience were used to establish estimated aircrew continuation training requirements for five mutually exclusive alternative methods of training for employment of laser guided weapons.

The main criterion used to evaluate the effectiveness of a proposed aircrew training system was whether or not it was judged by the individuals interviewed to be capable of maintaining an acceptable level of combat readinesss for the tactical air forces. Ten sub-criteria for tactical aircrew training systems were developed and applied to the five alternative training systems. Examples of the estimated economic costs of the resources required for each alternative to produce the required alternatives. Further study is suggested for a satisfactory method of measuring the effectiveness of laser tasked aircrews.

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